



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

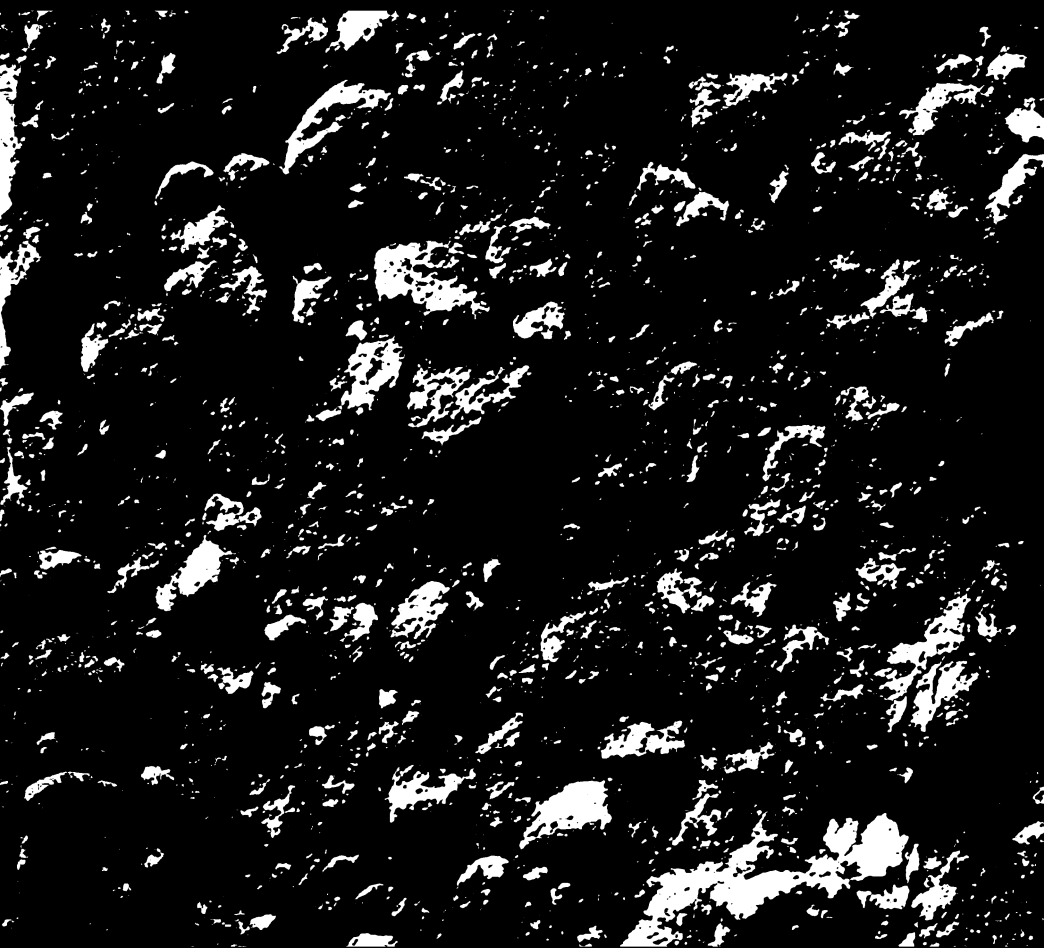
Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>



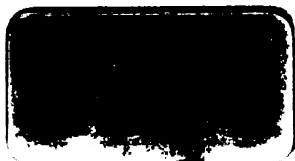
*The American
journal of science*



3 2044 106 428 642

73-10115
7.18-110
112-1

W. G. FARLOW



THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEORGE L. GOODALE, JOHN TROWBRIDGE,
W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS ADDISON E. VERRILL, HORACE L. WELLS,
L. V. PIRSSON AND H. E. GREGORY, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,

PROFESSOR HENRY S. WILLIAMS, OF ITHACA,

PROFESSOR JOSEPH S. AMES, OF BALTIMORE,

MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES

VOL. XIX—[WHOLE NUMBER, CLXIX.]

WITH TWO PLATES.

NEW HAVEN, CONNECTICUT.

1905

THE TUTTLE, MOREHOUSE & TAYLOR COMPANY.

CONTENTS TO VOLUME XIX.

Number 109.

	Page
ART. I.—Submarine Great Canyon of the Hudson River; by J. W. SPENCER	1
II.—Radio-activity of Underground Air; by H. M. DADOURIAN	16
III.—Types of Limb-Structure in the Triassic Ichthyosauria; by J. C. MERRIAM	23
IV.—Interaction of Hydrochloric Acid and Potassium Per- manganate in the Presence of Ferric Chloride; by J. BROWN	31
V.—Crystal Drawing; by S. L. PENFIELD	39
VI.—Anemiopsis Californica (Nutt.) H. et A. An anatomi- cal Study; by T. HOLM	76

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Production of Pure Sodium Hydroxide for Laboratory Uses, F. W. KÜSTER: Production of Magnetic Alloys from Non-Magnetic Metals, R. A. HADFIELD: Ozobenzol, HARRIES and WEISS, 83.—Concerning Emanium, GIESEL: School Chemistry, E. AVERY: Application of Some General Organic Reactions, LASSAR-COHN, 84.—Influence of Glass Walls of Geissler Tubes on Stratified Discharges in Hydrogen, E. GEHRCKE: Phosphorescence, P. LENARD and V. KLATT: Color Changes in Gold Preparations, F. KIRCHNER and R. ZSIGMONDY: Spectra of Hydrogen, Helium, Air, Nitrogen, and Oxygen in the Ultra-Violet, J. SCHNIEDERJOST, 85.—Pressure of Light, A. BARTOLI: Notes on X-Light, W. ROLLINS, 86.

Geology and Mineralogy—Indiana Geological Survey, W. S. BLATCHLEY, 87.—Geological Map of Indiana, T. C. HOPKINS: Geological Survey of New Jersey, H. B. KÜMMEL: Recent Seismological Investigations in Japan, DAIROKU KIKUCHI, 88.—Earthquakes, in the Light of the New Seismology, C. E. DUTTON: Minerals of Japan, T. WADA, 89.—Brief notices of some recently described Minerals, 90.

Miscellaneous Scientific Intelligence—Annual Report of the Regents of the Smithsonian Institution: Bulletin of the Bureau of Standards, 91.—National Academy of Sciences: American Association for the Advancement of Science, 92.

Number 110.

	Page
ART. VII.—Isomorphism and Thermal Properties of the Feldspars; by A. L. DAY and E. T. ALLEN. (With Plate I)	93
VIII.—Progress of the Albatross Expedition to the Eastern Pacific; by A. AGASSIZ	143
IX.—Measurement of Self-Inductance; by J. B. WHITEHEAD and H. D. HILL	149
X.—Climatic Features in the Land Surface; by A. PENCK ..	165
XI.—Preliminary Results with an Objective Method of Showing Distribution of Nuclei Produced by the X-rays, for Instance; by C. BARUS	175
XII.—Radio-active Measurements by a Constant Deflection Method; by H. L. BRONSON	185
XIII.—Convenient Apparatus for Determining Volatile Substances by Loss of Weight; by J. L. KREIDER	188

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Canyon Diablo Meteorite, MOISSAN: Metallic Calcium, K. ARNDT, 191.—Use of Dried Air in Blast-furnaces, LE CHATELIER: Trisulphoxyarsenic Acid, MCCAY and FOSTER, 192.—Electrolysis of Solid Electrolytes, HABER and TOLLOCZKO: Determination of Fluorine in Wine and Beer, TREADWELL and KOCH: Direction and Velocity of Electric Discharges in Vacuum Tubes, J. JAMES, 193.—Extinction of the Electric Spark, J. KOCH: Exhaustion of Geissler Tubes by the Electric Current, E. RIECKE, 194.—N-rays, A. BROCA: Recent Development of Physical Science, W. C. D. WHETHAM, 195.—Outlines of Physiological Chemistry, S. P. BEEBE and B. H. BUXTON, 196.

Geology and Mineralogy.—Geological Survey of Canada: Iowa Geological Survey, 196.—Glaciation in South Africa, M. E. FRAMES: Ueber Untersilur in Venezuela, F. DREVERMANN, 197.—Devonian Fauna of Kwataboahegan River, W. A. PARKS, 198.—Ueber den Bau und die Organisation der Lytoniidae Waagen, F. NOETLING, 199.—Tower of Pelée: New Studies of the Great Volcano of Martinique, A. HEILPRIN, 200.—Jüngerer Gesteine der Ecuatorianischen Ost-Cordillere, F. TANNHÄUSER: Älteren Gesteine der Ecuatorianischen Ost-Cordillere, F. von WOLFF: Ueber die Chemische Zusammensetzung der Eruptivgesteine in den Gebieten von Predazzo und Monzoni, J. ROMBERG: Heptorit, ein-haunyn-monchiquit aus dem Siebengebirge am Rhein, K. BUSZ, 201.—Kristallinen Schiefer, I, Allgemeiner Theil, U. GRUBENMANN: Yttrium and Ytterbium in Fluorite, W. J. HUMPHREYS; Hamlinite from Brazil, 202.

Miscellaneous Scientific Intelligence.—Publications of the Yale Observatory: Publications of the Yerkes Observatory, Vol. II, 1903, 203.—How to Know the Starry Heavens; a Study of Suns and Worlds, E. IRVING: Jefferis Mineral Collection: The Chemical Engineer, 204.

Obituary—DR. BENJAMIN W. FRAZIER.

Number 111.

	Page
ART. XIV.—Optical Constants of the Human Eye for different Colors ; by C. S. HASTINGS	205
XV.—Notice of the Discovery of a New Dike at Ithaca, N. Y. ; by V. H. BARNETT	210
XVI.—Dumortierite : by W. T. SCHALLER	211
XVII.—Crystallography of Lepidolite ; by W. T. SCHALLER	225
XVIII.—Machine-Made Line Drawings for the Illustration of Scientific Papers ; by R. A. DALY	227
XIX.—Iodobromite in Arizona ; by W. P. BLAKE	230
XX.—Antophytography : A Process of Plant Fossilization ; by C. H. WHITE	231
XXI.—Oxidation of Sulphites by Iodine in Alkaline Solution ; by R. H. ASHLEY	237
XXII.—Billings Meteorite : A new Iron Meteorite from Southern Missouri ; by H. A. WARD	240

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Atomic Weight of Iodine, G. P. BAXTER : Double Silicides of Aluminium, MANCHOT and KIESER : European, URBAIN and LACOMBE, 243.—Use of Calcium Carbide as an Explosive in Mining, GUÉDRAS : Silicon-fluoriform, RUFF and ALBERT : Double Cyanides of Copper, GROSSMANN and FORST, 244.—Occurrence of Radium and Radio-active Earths, F. GIESEL : N-Rays, E. GEHRCKE : Photography of N-Rays, G. WEISS and L. BULL : Spectra of Electric Discharges in Cooled Geissler Tubes, E. GOLDSTEIN : Dependence of the Ultra-Red Spectrum of Carbonic Acid upon Pressure, C. SCHAEFER, 245.—Electromagnetic Waves in the Visible Spectrum, F. BRAUN : Damping Galvanometer Deflections, W. EINTHOVEN : Possible Variation in Solar Radiation, 246.—Terrestrial Magnetism, L. A. BAUER, 248.—Introduction to the Study of Spectrum Analysis, W. M. WATTS, 249.—Reflecting Telescope : Theory of Optics, A. SCHUSTER, 250.—Elektrische Bogenlicht, W. B. VON CZUDNOCZOWSKI, 251.

Geology and Mineralogy—Treatise on Metamorphism, C. R. VAN HISE, 251.—United States Geological Survey : Geology of Perry Basin in South-eastern Maine, G. O. SMITH and D. WHITE, 256.—Preliminary Report on the Arbuckle and Wichita Mountains of Indian Territory and Oklahoma, J. A. TAFF, 257.—Oldest Sedimentary Rocks of the Transvaal, F. H. HATCH : Maryland Geological Survey, 258.—Palaeontologia Universalis : Melting Points of Minerals, A. BRUN, 259.—Mineral Resources of the United States, 1903, D. T. DAY, 260.—Elements of Mineralogy, Crystallography and Blowpipe Analysis, A. J. MOSES and C. L. PARSONS, 261.

Miscellaneous Scientific Intelligence—Report of S. P. Langley, Secretary of the Smithsonian Institution : Report of the Superintendent of the Coast and Geodetic Survey, 261.—Scottish National Antarctic Expedition : Nat. Academy of Sciences : Amer. Museum Journal, 262.—Reflections suggested by the new Theory of Matter, A. J. BALFOUR : Ideals of Science and Faith, J. E. HAND : Long-range Weather Forecasts, E. B. GARRIOTT : English Medicine in the Anglo-Saxon Times, J. F. PAYNE, 263.—Studies in General Physiology, J. LOEB : Early Stages of Carabidae, G. DIMMOCK and F. KNAB, 264.

Obituary—ALPHEUS SPRING PACKARD.

Number 112.

	Page
ART. XXIII.—Bearing of Physiography upon Suess' Theories; by W. M. DAVIS	265
XXIV.—Progress of the Albatross Expedition to the Eastern Pacific; by A. AGASSIZ	274
XXV.—Replacement of Quartz by Pyrite and Corrosion of Quartz Pebbles; by C. H. SMYTH, JR. (With Plate II)	277
XXVI.—Occurrence and Distribution of Celestite-Bearing Rocks; by E. H. KRAUS	286
XXVII.—Note on Interference with the Bi-Prism; by W. McCLELLAN	294
XXVIII.—Doughty Springs, a Group of Radium-bearing Springs, Delta County, Colorado; by W. P. HEADDEN	297
XXIX.—Error of Collimation in the Human Eye; by C. S. HASTINGS	310
XXX.—New Form of Electrode for Lead Storage Cells; by H. M. DADOURIAN	315
XXXI.—Chrysoberyl from Canada; by N. N. EVANS	316
XXXII.—Souesite, a native iron-nickel alloy occurring in the auriferous gravels of the Fraser, province of British Columbia, Canada; by G. C. HOFFMANN	319
XXXIII.—Absence of Helium from Carnotite; by E. P. ADAMS	321

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Properties of Methane, MOISSAN: Silicide of Carbon in the Cañon Diablo Meteorite, MOISSAN: New Process for Detecting Ammonia in Water, TRILLOT and TURCHET, 323.—Radio-tellurium, MARCKWALD: Conversations on Chemistry, Part I, General Chemistry, W. OSTWALD, 324.—Text-book of Organic Chemistry, H. LEFFMANN and C. H. LA WALL: Electric Inertia, S. H. BURBURY: Double Refractions, F. BRAUN, 325.—Emission Spectra of the Metals in an Electric Oven, A. S. KING, 326.—Dynamics of Particles and of Rigid, Elastic, and Fluid Bodies, A. G. WEBSTER: Experimentelle Untersuchung von Gasen, M. W. TRAVERS, 327.—Dynamical Theory of Gases, J. H. JEANS, 328.—Optical Pyrometry, C. W. WADNER and G. K. BURGESS, 329.

Geology and Mineralogy—Cambrian Brachiopoda with Descriptions of New Genera and Species, C. D. WALCOTT, 329.—Occurrence of *Mastodon humboldtii* in Northern Mexico, C. SHELDON: Petrography and Geology of the Igneous Rocks of the Highwood Mts., Montana, L. V. PISSON: Red Beryl from Utah, W. E. HILLEBRAND, 330.—Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada, A. E. BARLOW, 331.

Miscellaneous Scientific Intelligence—Studies in General Physiology, J. LOEB: Birds of North and Middle America, R. RIDGWAY: British Museum Catalogue, 332.

Number 113.

	Page
ART. XXXIV.—Physiographic Improbability of Land at the North Pole; by J. W. SPENCER	333
XXXV.—Bibliography of Submarine Valleys off North America; by J. W. SPENCER	341
XXXVI.—Interesting Variety of Fetid Calcite and the Cause of its Odor; by B. J. HARRINGTON	345
XXXVII.—Alternations of Large and Small Coronas observed in Case of Identical Condensations produced in Dust-free Air saturated with Moisture; by C. BARUS	349
XXXVIII.—New Circular Projection of the Whole Earth's Surface; by A. J. VAN DER GRINTEN	357
XXXIX.—Progress of the Albatross Expedition to the Eastern Pacific; by A. AGASSIZ	367
XL.—Note on the Names Amphion, Harpina, and Platymetopus; by P. E. RAYMOND	377
XLI.—Bragdon Formation; by J. S. DILLER	379

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Preparation and Properties of Tantalum, W. von BOLTON: Gravimetric Determination of Nitric Acid, M. BUSCH, 388.—Unity of Thorium, R. J. MEYER and A. GUMPERZ, 389.—Nitroxyl Chloride, GUTBIER and LOHMANN; Heusler Magnetic Alloys, E. GUMLICH: High Frequency Alternator, W. DUDELL, 390.—Deviation during Free Fall, DE SPARRE: Polarized Röntgen Radiation, C. G. BARKLA, 391.

Geology and Mineralogy—Plans for Obtaining Subterranean Temperatures, G. K. GILBERT, 393.—Vermont Geological Survey: Big "Cullinan" Diamond from the Transvaal, F. H. HATCH and G. S. CORSTORPHINE, 395.—Moissanite, a Natural Silicon Carbide, G. F. KUNZ, 396.—Occurrence of Palladium and Platinum in Brazil, E. HUSSAK, 397.—Platinum Resources in the United States, 398.—Beiträge zur Mineralogie von Japan, T. WADA, 399.

Miscellaneous Scientific Intelligence—National Academy of Sciences, 399.—Astronomical Observatory of Harvard College: Journal of Agricultural Science, 400.

Number 114.

	Page
ART. XLII.—Group of Visual Phenomena depending upon Optical Errors of the Human Eye; by C. S. HASTINGS.	401
XLIII.—Natural Iron-Nickel Alloy, Awaruite; by G. S. JAMIESON	413
XLIV.—Hyopsodidæ of the Wasatch and Wind River Basins; by F. B. LOOMIS	416
XLV.—Results of Late Mineral Research in Llano County, Texas; by W. E. HIDDEN	425
XLVI.—New Allotrope of Carbon and its Heat of Combustion; by W. G. MIXTER	434
XLVII.—Reflection of Light by Colored Papers; by H. D. MINCHIN	445

SCIENTIFIC INTELLIGENCE.

- Chemistry and Physics*—New Experiments in Preparing Diamonds, MOISSAN: Atomic Weights of Sodium and Chlorine, T. W. RICHARDS and R. C. WELLS, 451.—Origin of Radium, B. B. BOLTWOOD: Marcell Nencki, Opera Omnia—Gesammelte Arbeiten von M. NENCKI, 452.—Manual of Chemical Analysis as Applied to the Assay of Fuels, Ores, Metals, Alloys, Salts, and other Mineral Products, E. PROST: Radiation Pressure, POYNTING, 453. Spontaneous Ionization of Air in closed Vessels and its Causes, A. WOOD: Radio-activity and Chemical Change, N. R. CAMPBELL: Helium Tubes as Indicators of Electric Waves, E. DORN: Specific Heat of Water and the Mechanical Equivalent of Heat, C. DIETERICI: Photograph of the Solar Corona without a Total Eclipse, M. A. HANSKY: Kristallinische Flüssigkeiten und Flüssige Kristalle, R. SCHENCK, 454.—“N”-Rays, R. BLONDLOT: Elektrische Bogenlicht, seine Entwicklung und seine physikalischen Grundlagen, von CZUDNOCHOWSKY, 455.—The New Knowledge, R. K. DUNCAN: Percentage Tables for Elementary Analysis, L. F. GUTTMANN, 456.
- Geology and Mineralogy*—United States Geological Survey, 456.—Contributions to Devonian Paleontology, H. S. WILLIAMS and E. M. KINDLE, 460. Structure of some Primitive Cephalopods, R. RUEDEMANN, 463.—Notes on the Siluric or Ontario section of Eastern New York, C. A. HARTNAGEL: Trilobites of the Chazy Limestone, P. E. RAYMOND; Contributions to the Fauna of the Chazy Limestone on Valcour Island, Lake Champlain, G. H. HUDSON: Ueber Pteraspis dunensis, F. DREVERMANN: Notice of a new Crinoid and a new Mollusk from the Portage rocks of New York, R. P. WHITFIELD, 464.—Fossils of the Bahama Islands, with a list of the non-marine mollusks, W. H. DALL: Relations of the Land and Fresh-water Mollusk-fauna of Alaska and Eastern Siberia, W. H. DALL: Geological Survey of Ohio: Bahama Islands: La Montagne Pelée et ses Éruptions, A. LACROIX, 465.—Recherches géologiques et pétrographiques sur l'Oural du Nord, L. DUPARC et F. PEARCE: Einleitung in die chemische Kristallographie, P. GROTH: Grundzüge der Krystallographie, C. M. VIOLA, 467.
- Miscellaneous Scientific Intelligence*—Ascent of Water in Trees, A. J. EWART, 468.—Problems of the Panama Canal, H. L. ABBOT, 470.—Primer of Forestry, G. PINCHOT: Field Operations of the Bureau of Soils, 1903, M. WHITNEY: Mechanism, S. DUNKERLEY, 471.—British Museum of Natural History, Birds, W. R. OGILVIE-GRANT: Catalogue of the Lepidoptera Phalænæ in the British Museum, G. F. HAMPSON: Geographen-Kalender, HAACK: Publications of the Carnegie Institution, 472.—Cold Spring Harbor Monographs, M. E. SMALLWOOD: Science Bulletins of the Brooklyn Institute of Arts and Sciences: Project for the Panama Canal, L. W. BATES.
- Obituary*—HENRY R. MEDLICOTT: PROFESSOR PIETRO TACCHINI: PROFESSOR OTTO STRUVE, 473.

INDEX TO VOL. XIX, 474.

T H E

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Submarine Great Canyon of the Hudson River;*
by J. W. SPENCER, A.M., Ph.D.*

CONTENTS :

An Account of what has been done before this date.
The Hudsonian Canyon.
Surface Channels of the Continental shelf, and the Deep one of the Connecticut.
Constitution of the Continental shelf.
Origin of the Canyon.
The Magnitude and the Time of the Great Elevation.
Summary and Conclusions.

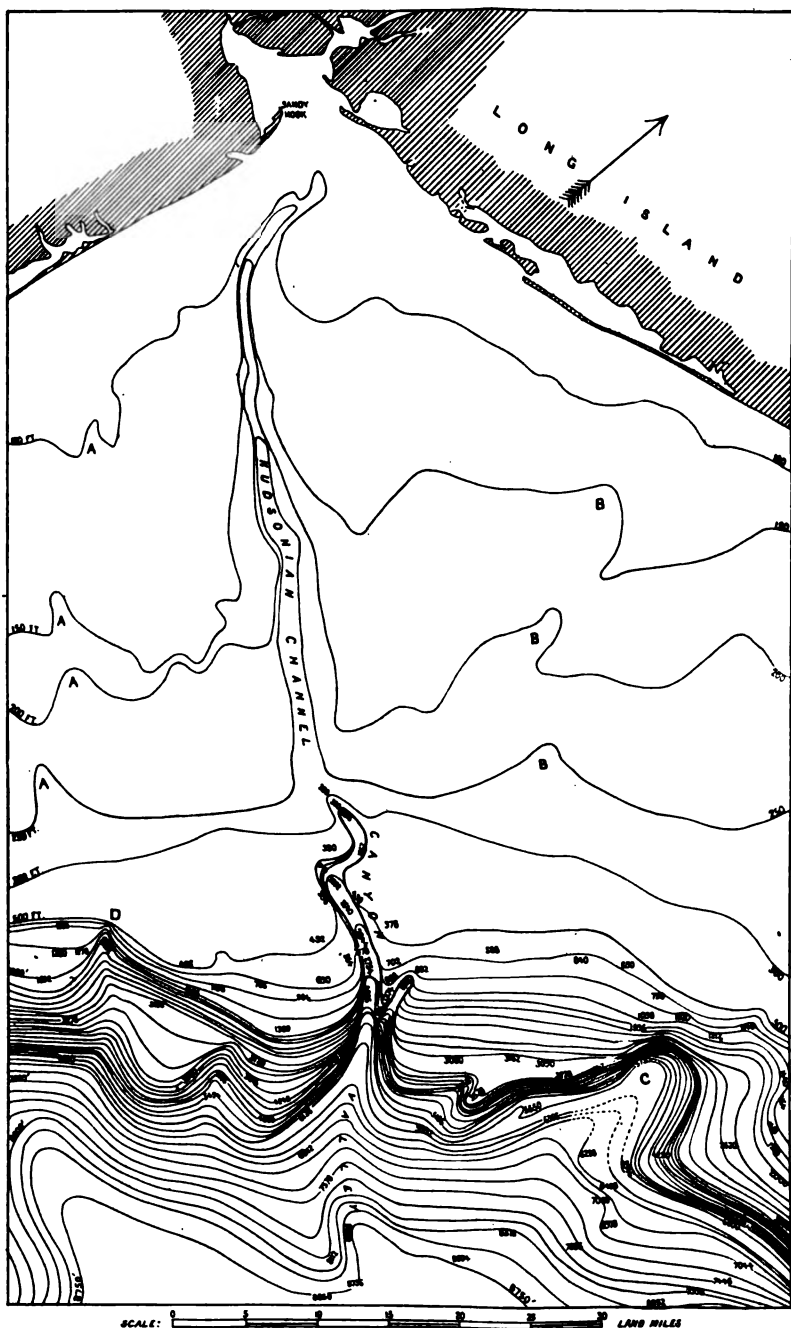
An Account of what has been done before this date.

The early work of the Coast Survey brought to light a depression extending from near New York to the border of the Continental shelf. Prof. J. D. Dana was the first to recognize this feature as the submerged channel of the Hudson River, formed when the continent stood at a greater altitude above the sea than it does now. So much importance did he attach to it, as evidence of terrestrial oscillations, that a map of it appeared in all the editions of his *Manual of Geology*, since 1863, but only in the latest edition (1895) was it shown to reach to a greater depth than 720 feet. In the last revision the upper channel and the canyon sections are distinguished, the latter to a depth of over 2000 feet. But the discovery of the canyon was first announced by Prof. A. Lindenkohl in 1885† and further discussed in 1891.‡ He found that it reached to a depth of 2844 feet where the adjacent continental shelf was submerged to only 420 feet—a gorge of 2400 feet in

* This paper will simultaneously appear in the *Geographical Journal* of London.

† This *Journal* (3), vol. xxix, pp. 475-480, 1885.

‡ *Ib.*, vol. xli, pp. 489-499, 1891.



Map of the Submarine Great Canyon of the Hudson River (by J. W. Spencer).

Soundings in feet. Isobathic lines 250 feet apart, from that of 500 feet to 8,750 feet. Very numerous soundings on continental shelf to 500 feet where the isobaths are 50 feet apart. A A A and B B B show course of streams during a late Pleistocene elevation of 250 feet. C is position of the Connecticut canyon or valley, west of which are blank spaces in which the corrected soundings should be 1,896 and 2,340 feet.

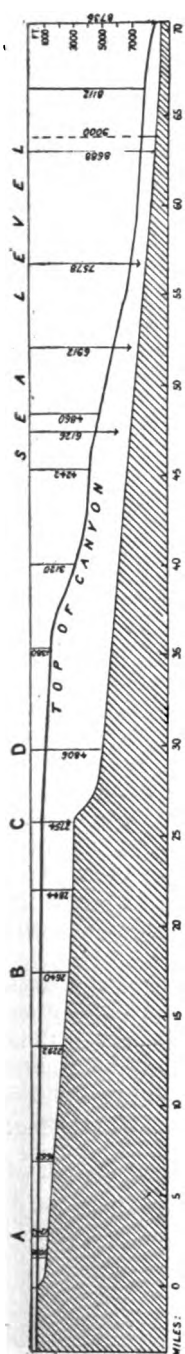


FIGURE 1.—Longitudinal section of Submarine Great Canyon of the Hudson River. At points where depths end in arrows the soundings were not taken in center but on side of the valley. A, E, B, C, D, location of cross sections. E is situated 4 miles above B. Soundings given in feet. Since going to press, from additional information, abrupt steps of 400 and 500 feet respectively are found to occur in the gradient just above depths of 1662 and 2292-foot soundings.

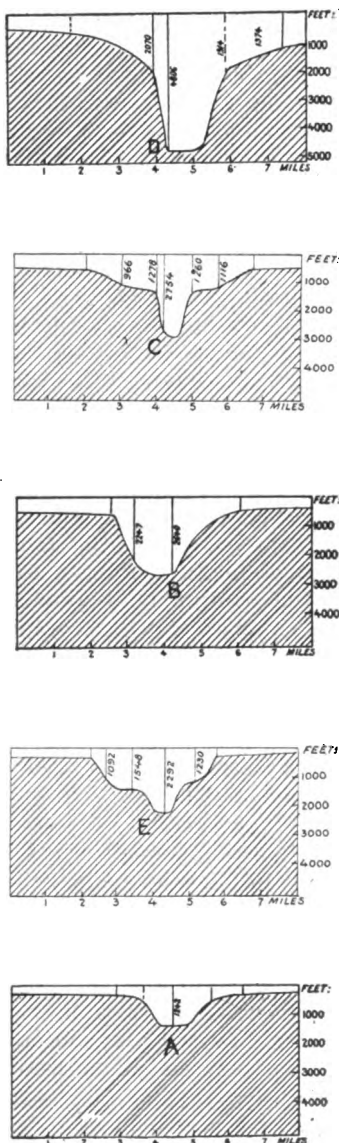


FIGURE 2.—Cross sections located at A, E, B, C, D, in longitudinal sections. Their position on map corresponds to similar depths, in feet, there shown. E (at a point 4 miles above B) and C show the double character of the canyon.

depth. From the soundings beyond the deep point, he at first thought a bar of 1600 feet in height crossed the mouth of the canyon.

In 1889, I pointed out that this canyon, along with those at the mouth of the Gulf of St. Lawrence and of the Maine, could be taken as yardsticks in measuring the late continental elevation to the extent of 3000–3600 feet. This was in the second paper published by the Geological Society of America, the first being by Prof. Dana.*

A few months later Dr. Warren Upham cited the Hudson canyon among the evidence he brought together to show that elevation was the cause of the glacial period.† In it he attributed the apparent bar to the action of coastwise wave-wash during the subsidence of the continent after the formation of the gorge. Though this bar was a large order for wave action, it was the only reasonable explanation of the deep hole if such it were, as suggested by the Coast Survey chart.

Again in 1890, Prof. Dana published a paper,‡ in which he says that the channel “affords strong evidence of the river origin and therefore the whole channel up to New York was once the course of the Hudson.” In the last edition of his *Manual* he further says (page 948) that the former emergence of the continental border now sunken is proved by the Hudson submerged valley, citing also the cases of the canyons of the gulfs of St. Lawrence and Maine, mentioned above, as evidence of the elevation of the region in the glacial period to at least 3000 feet. It may be here stated that Prof. Dana, on seeing my account of the submarine valleys of the West Indian region, wrote to Prof. Lindenkohl, who replied that he was not aware of them, and hence the note in his *Manual* concerning them (page 949). Prof. Lindenkohl, however, later accepted my interpretation of the much deeper valleys§ which Dana doubted, confirmed by Prof. Lindenkohl’s want of knowledge at the time, though Prof. Dana accepted my St. Lawrence canyon to 3600 feet below sea level.

In 1897 I read a paper before the British Association, stating that with the very insufficient soundings, the Hudsonian valley was recognizable to a depth of 12,000 feet,|| illustrating how we may anticipate where canyons may be found. This paper, amplified into “The Submarine Valleys off the

* “The High Continental Elevation preceding the Pleistocene Period,” *Bull. Geol. Soc. Am.*, vol. i, pp. 65–70, 1890.

† *Bull. Geol. Soc. Am.*, vol. i, p. 563. Also *Geol. Mag. Lond.* (3), vol. vii, p. 494, 1890.

‡ “Long Island Sound in the Quaternary era, with Observations on the Submarine Hudson River Channel,” *this Journal* (3), vol. xl, p. 425, 1890.

§ *Bull. Geol. Soc. Am.*, vol. xiv, p. 226, 1903.

|| *Ib.*, pp. 207–226.

American Coast," in 1902,* taking such phenomena as a whole, showed there was accumulative evidence suggesting that these submarine features were gauges for measuring the late great continental elevation.

The most recent discussion including that of the Hudsonian channel (1904) is in Dr. F. Nansen's epoch-making monograph on continental shelves and previous oscillations of shore lines,† reserved for later consideration.

The Hudsonian Canyon.

The channel described by Lindenkohl begins about ten miles off Sandy Hook and extends for 93 miles before it plunges into the canyon. Land miles and not sea miles will be used throughout this paper. At its head, opposite Sandy Hook, the channel is buried by the sand of the coastwise drift-forming bars, though nearer New York it is much deeper. Lindenkohl had described the depth of the canyon to 2844 feet below sea level, with a bar in front, and no further information is shown on the U. S. Coast Survey charts. In revising my last mentioned paper, I found much additional data on the charts issued by the Hydrographic Office, greatly strengthening the evidence of the continuation of the Hudsonian valley, extending down the continental slope to great depths. But on the British charts I made a most astounding find of three soundings of 459, 801 and 229 fathoms. The position of the 459 and of the 801 soundings of the British chart so closely coincided with those of the Coast Survey chart‡ at 213 and 345 fathom points that they could not have been represented on the same charts. Thus the British chart showed no barrier to the canyon and very greatly increased the known depth of the narrow gorge, further defined by the 229 fathom point. The extraordinary depth would have been startling had it not been anticipated in all of my long series of analyses of submarine valleys. Both series of soundings were correct, the deeper ones having been made by Lt. Com. Z. L. Tanner§ in 1883 in the Fish Commission steamer Albatross. The older soundings had been retained on the Coast Survey charts.

The canyon of the Hudson River may now be extended and revised as follows: The mean edge of the continental border may be taken at a depth of 450–500 feet below sea level. The head of the canyon, in a direct line backward of the edge of

* *Ib.*

† "The Bathymetrical Features of the North Polar Seas, with a Discussion of the Continental Shelves and Previous Oscillations of Shore Lines," by Fridtjof Nansen. Quarto, pp. 1–232, plates 28. Published in English by the Fridtjof Nansen Fund for the Advancement of Science, Christiania, 1904.

‡ Coast Survey Chart, No. 8. B. A. Chart No. 2480.

§ Hydrographic Notice to Mariners, No. 56, 1883.

the shelf, is 20 miles, but its course is somewhat longer. The upper channel has a depth of 42 feet in the very level sandy plain, which is then submerged to only 288 feet (though a hundred miles from New York harbor). At this point there is an abrupt descent from the bed of the upper part to 1098 feet in the canyon, within the distance of about a mile. The gorge soon deepens to 1242 feet, where cross section A is taken.

The canyon extends nearly due east for six miles, where its depth reaches to 1662 feet. It then bends sharply at right angles to the south, and at 12 miles from its head a narrow inner gorge descends from 1770 to 2292 feet (in a distance of 1.5 miles) where the broad outer canyon attains a depth of only 1500 feet below sea level. Here the shelf is submerged about 250 feet, accordingly the outer and inner canyons have respective depths to 1250 and 2050. A cross section is shown in figure E (added since paper went to press) which is located near the soundings of 2292 feet shown on the map and longitudinal section. Here the canyon turns again at nearly right angles towards the east, though farther on it bends slightly southeastward. A depth of 2640 feet is reached in 18 miles, where cross section B is taken. At 23 miles the depth is 2844 feet, and at 26.5 miles is the position of the 213-fathom sounding, which was supposed to have indicated a bar, and close against which is the discovered sounding of 459 fathoms, as shown in the precipitous wall in cross section C. Nearly midway between these soundings is one of 457 fathoms (the last two not being situated quite in the center of the channel). These, with others on record, but not shown on the published charts, form a chain of soundings from one to two miles apart reaching to near the floor of the inner gorge, thus establishing its continuity. At this locality also, unpublished soundings further show the double canyon, the outer of which, with a breadth of four miles, is revealed to a depth of 1200–1300 feet below sea level, while the inner has a width not exceeding one mile but reaches to over 2800 feet. The gradients and depths of the canyon and their relation to sea level are shown in the longitudinal section figure 1. At 31 miles the 801 fathoms is found, close against that of 345 fathoms not shown on map. This last is on the side of the gorge, of 3800 feet, where the continental slope is further submerged 1000 feet. Here, too, is a great downward pitch in the gradient of 2000 feet in four miles. At this point the maximum breadth of the gorge, nearly 3800 feet above the floor of the canyon, does not exceed two miles, with the bottom necessarily narrower. Seemingly part of the slope of the wall where the deep sounding was found approaches 60 degrees. At 34 miles there is a short tributary from the north, heading in a typical

cove. Beyond this point, where the sounding is more than 4806 feet deep, the canyon feature must continue for several miles at least. I have carried it to the 42-mile point, where the continental shelf is submerged to 3000–3500 feet. At this depth we have several soundings which show that the 3000-foot isobath continues in a direct line as if across the canyon without any known suggestion that it sweeps round into the form of a broadened embayment. Its parallelism to the 500-foot line of the edge of the shelf shows the remarkable regularity of this zone of the great slope. There is also suggested the remains of a shelf or bench of depth corresponding to the Blake plateau south of Cape Hatteras.

Within a few miles the canyon appears to broaden out, and yet at 48 miles there is a steep cliff of 2000 feet or more on its southern side. Here the floor exceeds a submergence of 6126 feet, as the measurement is not in the center of the valley, nor have we obtained the sounding on the opposite northern edge, the last in the gorge being 4800 confined within walls of 3800 feet, though the walls are known on both sides lower down. Indeed this depth is still below that of the continental slope at 48 miles. Evidently the canyon section must reach to a depth of from 6000 to 7000 feet, which also corresponds to the deep valley of the Connecticut. (C on map.)

Beyond the canyon section is the southern side of the extended valley, demonstrated by a line of soundings, though not at its summit. The four soundings at about 8688 feet are specially important as proving the continuation of the Hudsonian valley. The first of these is at 63 miles. At 67 miles the lateral bank is at least 624 feet high (probably 1000 feet at least above the floor), and our record carries the valley to 71 miles from the head of the gorge. The end of this lower reach does not exceed 14 miles in width, but fuller soundings may limit it to 8 or 10 miles. Thus the valley is shown to exist to a depth of 9000 feet.

Beyond this point there are no soundings in the line of the valley, but lateral ones on both sides are suggestive, and at 100 miles east of this study, at a little less than 12,000 feet, is an embayment of 30 miles in breadth, with the depth of a few hundred feet. This cannot be a meaningless feature, though not part of the present analysis.

The breadth of the canyon hardly exceeds a mile at its head, but it soon widens to two miles or more. From the second turn (see map) a breadth of four miles is maintained for the outer canyon. The deeper inner gorge is reduced to a width of one mile or less, and is more sinuous than the outer. Beyond the tributary it is wider, five or six miles, though possibly more, as the next sounding is farther away, but a little

greater or less detail does not alter the general features, and the only important points left relate to the question of the canyon opening out into the valley and its depths, which the analysis shows is 6000–7000 feet, and farther on the characteristics are those of a valley rather than a canyon to 9000 feet below sea level.

Surface Channels of the Continental shelf and the Deep one of the Connecticut.

The surface of the continental shelf is a marvellously flat plain, with a mean slope not exceeding three feet per mile. This condition represents a flat substratum, even though there may be hollows in it levelled over by sand deposits. Nearer than Long Island there is no trace of a moraine either buried or submerged. The surface of the plain is covered over with sea-washed sand, except in the Hudsonian channel. This adjective termination I have long used to designate the drowned sections of the river valleys. The sandy plain is traversed by shallow channels shown on each side of the map at AAAA and BBB. These would be still better followed if more isobathic lines were introduced. It is to a depth of 250 feet that these channels are most noticeable. They represent the stream action of an epoch of elevation to this amount since the time of canyon making, and subsequent to the levelling over of the plain after that date. That is to say, these channels absolutely belong to a post-Columbia or Pleistocene epoch,—the canyons to a pre-Columbia or early glacial time. During Columbia oscillations wave action has obliterated all traces of delta form.

The channel of the Hudson river in crossing the submarine plain shows a bottom of blue clay with sandy material in places. But the course of the old upper channel must have been still defined to have allowed its reopening during the epoch of reëlevation of 250 feet just mentioned.

In the canyon section, the bottom is composed of blue clay with fine sand. Beyond it the continental slope is also surfaced with blue clay or green clay, as shown by many soundings.

The great Connecticut canyon or valley, asked for by Lindenkohl,* is represented (at C on the map) by a deep embayment, whose west wall is at least 3600 feet high, and it reaches to a depth of 5736 feet below the surface of the sea, but the information is not at hand to define its form, though a canyon perhaps passing into a valley at this point might be expected.

At D, on the other side of the map, one sees a cove or amphitheatre such as are commonly indenting the borders of high

* Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

plateaus. I may have too strongly represented the feature on the map, but it is not one of special importance.

Constitution of the Continental Shelf.

All our classic teaching tells us that, during the earlier and middle Mesozoic era and far into the Cretaceous period, the continent here was so elevated and subjected to denudation that the sediments were carried far seaward. We cannot go into the question as to their covering the continental slope, but it would seem that the continental shelf now submerged was subjected to the same conditions as those now underlying the coastal plains of the adjacent lands. On these we learn that besides a few hundred feet of Potomac sands, which probably thin out, there are deposits of sand, greensand, clay and clay marl of the upper Cretaceous formations reaching a thickness of 800–1100 feet. Then follow some Eocene sands succeeded by clayey, marly and sandy beds belonging to the Miocene beds. These occur in an artesian well boring at Atlantic City, reaching to a depth of 1400 feet (without penetrating the series or the limited Eocene sands or obtaining water at the lower depths though somewhat higher fresh water occurs, indicating the leaching out of the salt sea water during an epoch of elevation). All below 265 feet is Miocene. This upper part is composed of sand gravel and clay, which may represent important features requiring a word of explanation. Of red gravel sand and stiff clay loam are composed both the Lafayette and Columbia formations, each of which is a thin sheet except where filling valleys. The Lafayette is provisionally regarded as belonging to the end of the Pliocene period, occurring below morainic material as I have seen in New Jersey. But it has been enormously denuded. The Columbia formation (now subject to subdivision) is the material of the Lafayette redeposited, and overlies the drift, with its surface only moderately sculptured. I should suspect that at Atlantic City is a buried channel filled mostly with these deposits of the Columbia period, capped with more recent alluvium. These upper beds are substantially horizontal, with the Miocene dipping a little more. For the details of the Miocene deposits in the Atlantic City well see the paper by Mr. L. Woolman*.

Thus not knowing whether these incoherent formations have a greater or less aggregate thickness, beneath the submerged coastal plains, there are only known little over 2200 feet to be accounted for from the adjacent shores. But they have formed the subsurface of the level plains now submerged, and channelled by the drowned Hudson river, and finally incised by

* Acad. Nat. Sc., Phil. 1887, p. 339, and vol. for 1890, pp. 132–147.

the canyon on the continental border. Here then, in its upper portion, the gorge penetrates easily denuded material, though some of the beds are composed of remarkably tough clay. Where the sides of the canyon are so precipitous as was shown at the 459 and 801-fathom isobaths, we may suppose that the lower portions are cut out of the harder older rocks, succeeded by more yielding material farther down the submarine valley.

Origin of the Canyon

It appears that the previous students of the submarine channel have all had the idea that it was formerly a land valley. Such analysis of the phenomena as has been given must be used in discussing its origin under any other hypothesis. While a few other soundings are desirable for fuller local details, we need not one more for a reasonably full discussion of the principles involved—only enough are wanting to stimulate interest in a revision. Not to speak of similar phenomena farther south and in the West Indies discovered by myself,* and those since brought to light and systematized in a brilliant manner by Prof. Edward Hull of London, situated on the eastern side of the Atlantic basin,† I shall mention the canyon of the Congo discovered by Stassano, and worked out by Mr. J. Y. Buchanan and described by Mr. Edward Stallibrass, and the canyon off Cape Verde described by Mr. Henry Benest, on account of the completeness of detail of such features, not hitherto obtained, but with which the Hudsonian canyon can now be grouped with the advantage of our knowledge of the surrounding physiographical and geological environments, and with the further interest in that it is situated at the main door of the continent.

If formed by river action, the Hudsonian canyon affords proof of startling physical conditions of the region, at a very late date, and hence the whole interest in its origin, for if now a land feature, it would be one of not such unusual occurrence as to awaken our amazement. Can the views of the earlier writers be challenged? The only other possible causes of its origin seem to be:—(1) submarine glacial erosion, (2) open faults, (3) submarine rivers, and (4) a remnant of a primitive depression. This last would only be suggested by an obstinate objector to its fluviatile origin, or one unfamiliar with the analyses of such subjects; for after passing the Paleozoic evolution of the continent, what is now its great slope should be covered with detritus carried into the sea during the long period of denudation of the Mesozoic era, thus obscuring older depressions. Some of the African canyons have been attrib-

* "Reconstruction of the Antillean Continent" and other papers in Bull. Geol. Soc. Am. and in Quar. Jour. Geol. Soc. London.

† Published by the Victoria Institute, London.

uted to submarine rivers. By this the hypothesis of a great elevation of the continent was avoided. There seems nothing in its favor beyond the occurrence of river valleys at great depth, and some floating debris on the sea. As Prof. N. S. Shaler says, subterranean channels must be formed above the base level of erosion; and the establishment of such must precede that of submarine rivers, which soon lose their effectiveness.

Can the question of canyons be cavalierly disposed of by calling them faults? The level continental shelf is covered with Tertiary sands and clays, such as would not favor an open fault theory. The submarine topography on both sides is identical, suggesting not the slightest disturbance to leave an open fault, nor is such shown on the land adjacent. Joints and faults may locate valleys, but the submarine shelf is only a new plain prolonging the Hudson valley, which in slowly rising would force the water to follow the lowest course. The fault theory is not supported by the Great Valley of the Appalachians, extending for a thousand miles, with a breadth of from 20 to 40 miles. And it is in a region abounding in fault; yet the valleys, as have long since been shown by Professors Lesley and Dana, and others, are those of denudation and which I have confirmed in Georgia. Even the gorge of the Delaware Water Gap, where more than a tyro might be pardoned for suspecting a fault left open, is not such according to Professor Lesley and Mr. Chance the geological surveyor of it. The submarine canyon of the Hudson, which is double, the inner the more sinuous, does not lie in a direct line, but turns twice at right angles within a distance of a dozen miles, and below, it widens into a fan-shaped valley. Nansen has described many submarine valleys in the continental shelf of Norway and about Iceland, and does not find it necessary to call in the existence of faults, and even where my evidence has not been full in treating deep submarine valleys, he thinks there is no other feasible explanation, than that the valleys are sunken land features (page 192). Nor will those who appeal to Sir A. Geikie find much comfort in faults. He says:—"To many geologists the mere existence of a valley is evidence of the presence of a fault," and that "in every case actual proof of a fault should be sought for in the tectonic structure of the ground." "In the vast majority of cases in Britain valleys have no connections with faults." From its forms and its associations I think we can dispense with the idea of a fault-made rift, unaffected by atmospheric action; and furthermore, this is not in the region of apparent great tectonic disturbances, but one of remarkable simplicity since in Cretaceous times.

Finally I know of no other reason for appealing to faults as

the cause of such a submarine feature, except as a last resort from accepting the evidence as is set forth in this paper, unless such a reason can be shown to exist other than by negative or insufficient evidence.

As for submarine glacial erosion, I have shown that there are no features of the shelf suggestive of the occurrence of glacial action, even though such reached to Long Island and New Jersey. Furthermore it could not have possibly extended to the great depths of the canyon and the continuing valley. Of this question Dr. Nansen says in his great monograph:—"The drowned valley of the Hudson River cannot possibly have been re-opened by submarine glacial erosion, it is too long and narrow and deep." (Op. cit. p. 192.) Its analogues of the tropics are situated beyond glacial action.

Of the drowned valley of the Gulf of St. Lawrence, Prof. N. S. Shaler also writes, but I do not remember whether he considers the then discovered Hudson River canyon.

Returning now to long accepted fluvial origin of the submarine channel, let me call attention to the very close resemblance of the canyon, as shown on the map, to the gorge of the Niagara, also excavated out of level plains, far from mountains, in front of which are great slopes to lower levels. But this portion of the Hudsonian canyon is thirty miles long and reaches to thousands of feet in depth, while that of the Niagara is only seven miles in length and now 440 feet deep. So too the canyon of the Hudson is just like the *barrancas* on the high plateaus of Mexico and Central America, starting in level plains, and then suddenly transforming themselves into rapidly descending canyons, which later widen out into such valleys (as we may see in the east, which have reached more mature forms), whose descent from the plateaus of thousands of feet in height is not by regular gradients, but commonly by a succession of great steps.

The Magnitude and the Time of the Great Elevation.

While it must have taken the Hudsonian canyon many milleniums to have been formed, yet it presents a youthful feature, in strong contrast with the valleys on the eastern side of the American continent, while its submerged marginal shelf is not deeply indented with its surface scored into a succession of ridges and hollows. Even though many of the underlying rocks may be of a resisting nature, yet the period of canyon-making must have been one of limited duration. This is further suggested when considering the size of the Hudson river, which probably carried down glacial waters and detritus for a portion of the period. Outside the limit of the Hudsonian river, the surface of the now submarine plain was

not deeply scored as with atmospheric agents acting for long ages, as would have appeared beneath the superficial mantle had such obtained. One condition might modify this last argument, namely a subsequent long epoch of wave cutting, with the removal of the prominences, such as Nansen describes in his "coast platform" which does not exist here, but in such a case the Hudsonian gorge should have been filled with debris.

In the region of the Great Lakes from the tilting of beaches, I have worked out great epirogenic movements, and it quite prepares me to expect to find a reduction of the amount of elevation of the continent, represented by the present submergence of the valleys along our continental margin due to bending downward of the continental slope, but this would not reduce by any amount that determined in the canyons and the necessary slope of the land surfaces. So also when we find subaerial features submerged, they at least would need to have been depressed to the depth they are now found at, no matter what the cause of depression.

The canyon section has sunken 6,000–7,000 feet and the valley beyond to 9,000 feet. Did I attempt to guess at the reduction of this amount in the late height of the continent, I should be inclined to pause owing to other features outside the line of this study. But if others wish to reduce the continental elevation by 2,000 feet, by extra bending down of the continental slope, I shall not protest farther than by stating that additional evidence beyond our limit may replace it. Provisionally then we may keep the amount of elevation at 9,000 feet as shown here, leaving others to correct the figures if found to be excessive. On the other hand, I have no idea that the present heights of the mountains were relatively nearly so great as now.

Fragments of the Lafayette formation should extend from New Jersey, and underlie the surface of the continental shelf. The great denudation of the region was after the Lafayette period, as was proved by Prof. W. J. McGee. I have found these beds underlying glacial deposits in New Jersey. They are provisionally regarded as Pliocene, unless they are pre-glacial Pleistocene, as thought by Upham. On the surface of the overlying till, rests the Pleistocene Columbia red loams, sands and gravels, in samples not distinguishable from those of the Lafayette formation except in the smaller size of the gravel. And it is such materials which are obtained in the Atlantic city well (Woolman). The denudation of the Lafayette has been so extensive that its remains would be more likely outside of a channel, buried as this appears by the Columbia formation, which has levelled over and furnished materials for the surface of the continental shelf before the

re-excavation of the small channels at AAAA and BBB on the map (page 2). These channels as mentioned before, represent a re-elevation of the drowned plain to as much as 250 feet in the later Pleistocene period, since which time the region has been again once or twice depressed, then re-elevated slightly and channelled, and is now sinking at the rate of two feet a century (Prof. Mitchel). All of the changes are remarkable repetitions of those which I have shown to have occurred farther south and in the West Indies. Thus it may be seen that the canyon-making period was in the earlier Pleistocene, and accords with Prof. Dana's views as expressed in the last edition of his *Manual*, and those of Dr. Upham, only the evidence is in more detail, showing a much greater elevation than was then known.

I have not touched upon an earlier Tertiary valley, as such could apply only to great depths beyond the canyon section.

Summary and Conclusion.

More than 40 years ago, Prof. J. D. Dana first recognized the submarine extension of the Hudson river in the soundings on the continental shelf. In 1885, Prof. A. Lindenkohl discovered the channel suddenly transformed into a canyon near the continental border, reaching to a depth of 2400 feet below the surface of submerged plain, which is here about 400 feet beneath sea-level. But near the then known mouth there appeared a great bar. In 1897, I pointed out that the channel was traceable to great depths, which is now proved. A sounding was made near the supposed bar, which has proved to be only a measurement taken on the side of a deep canyon with a precipitous wall. Then four miles beyond this point, against another lateral bank, a further sounding reaches to 4800 feet, revealing a canyon 3800 feet in depth, where the continental shelf is not submerged more than 1000 feet. High up on the sides, the gorge here is less than two miles wide, but the incision of the outer canyon into the shelf has a breadth of four miles. At its head, the canyon begins in an amphitheatre, having a descent from 330 feet to 1100 feet in the distance of about a mile. Two more steps of 400 and 500 feet respectively follow. Again between 27 and 31 miles below its head, there is another great step of 2000 feet to the depth of 4800 feet mentioned. And the gradient below is probably by other great steps. This is just beyond the border of the submarine plain and shows the canyon with a depth of 3800 feet. The canyon is double, a second or more sinuous gorge traverses the outer. A little farther on is a tributary heading in a cove. At 42 miles the canyon begins to widen into a valley, which at 48 miles has a precipitous wall of 2000 feet in height. The valley opens

into an embayment or wider valley which also receives that from the Connecticut, now discovered to a depth of about 6000 feet for the first time, but without details to describe its form. In cutting through the continental bench, at 3000–3500 feet beneath sea-level, the floor of the canyon is between 6000 and 7000 feet below the surface of the ocean. The valley is continuous to a point 71 miles from the head of the gorge and where it is recognizable at a depth of about 9000 feet.

The canyon and valley discovered to the great depth shown, incising first the level continental shelf, (in which it turns twice at right angles), and then coursing down the great continental slope, is now taken as a gauge for measuring a late high continental elevation of the region to the extent of 9000 feet. This is following out the lines of Dana, Lindenkohl and other students of the submarine channel, in that they considered it a drowned land valley. I have analyzed every other known possible cause of its origin. So great are the probabilities and so long have these been accepted unquestioned, that very strong proof would be required to modify this view.

The period of the great elevation has been found to coincide with that of the early Pleistocene. Since then there has been a subsidence to somewhat below the present level, followed by a re-elevation of 250 feet as seen in the shallow channels of the shelf. With other minor changes, the region is now sinking at the rate of two feet a century.

This canyon feature at our door corroborates the great changes of level worked out most extensively by Hull of Britain, Nansen of Norway, and myself here and in the West Indies, following methods which the father of geography, Prof. J. P. Lesley, predicted in 1888 "must throw light on the whole subject of elevation and subsidence, as applicable to the entire area of the United States."

ART. II. — *Radio-activity of Underground Air*; by
H. M. DADOURIAN.

ATMOSPHERIC and underground air have been shown to be radio-active by Elster and Geitel,* and others. Experiments, by several investigators, on the rate of decay and other properties of the atmospheric radio-activity have proved it to be due to the presence of a radio-active gas similar to radium emanation. The activity of this radio-active gas decays just about as fast as radium emanation, that is, it falls to half value in about three days and a half. But the rates of decay of the excited activities obtained by exposing a negatively charged wire to the air and to radium emanation do not agree so well. Rutherford and Allan† obtained 45 minutes for the half-value period of air excited activity, whereas radium excited activity falls to half value, after the first two hours, in 28 minutes.

This is to be expected if we suppose that there is thorium emanation in the air as well as radium emanation. Thorium emanation decays very rapidly, having a half-value period equal to about one minute; so the experiments on the rate of decay of the radio-active gas obtained from the air determine the rate of decay of the radium emanation in the air only, the thorium emanation having decayed during the few minutes which it takes to begin to observe the ionization currents, after the removal of the difference of potential from the negatively charged wire. This accounts for the close agreement between the rates of decay of the ionizations of radium emanation and the radio-active gas obtained from the air. On the other hand, the excited activity obtained by exposing a negatively charged wire to the air, decays very much more slowly than radium excited activity; the half-value period of the former is about 11 hours while that of the latter is 28 minutes. Thus measurements of the rate of decay of the air excited activity give the rate of decay of a combination of the excited activities of radium and thorium. In fact, Bumstead‡ has recently shown that the excited activity obtained by exposing a negatively charged wire in the open air is fairly accounted for by the assumption of the presence of radium and thorium emanations in the air.

The following experiments were undertaken in order to see if this was the case with the excited activity obtained from underground air, also. The method employed in taking the ground-air excited activity is illustrated in figure 1.

* Elster and Geitel, *Phys. Zeit.*, iii, p. 574, 1902.

† Rutherford and Allan, *Phys. Mag.*, Dec., 1902.

‡ Bumstead, *this Journal*, xviii, 1, 1904.

A circular hole, AA, 50^{cm} in diameter and 200^{cm} deep, was dug in the ground. At the top of the cavity was plastered a rectangular board, CC, with a circular opening 40^{cm} in diameter. A sheet metal cover, D, screwed on to the board, over a rubber gasket, served as a partition between the outside air and the air inside the cavity. BB is a wooden frame, which consists of a 175^{cm} long rod, provided with a circular board, of 30^{cm} diameter, at each end. A piece of copper wire, $\frac{1}{4}$ ^{mm} thick and about 50 meters long, was wound about the frame, so as to form a cylinder. The wire was put into this form in order to have it as near the walls of the cavity as possible, also to secure a larger field. This cylinder of wire was then hung from a hook, E, which was insulated from the sheet metal cover and was connected to the negative terminal of a Wimshurst machine, the other terminal being to earth.

The wire was charged for three hours, keeping a parallel spark-gap of about 2^{mm}. In the meanwhile the air in the cavity was sucked out by means of a filter pump, connected to the stopcock, F, in order to bring fresh underground air into the field of the negatively charged wire. At the end of three hours the wire was removed from the wooden frame and was put into a testing vessel. This was a cylindrical condenser

which consisted of a galvanized sheet-iron cylinder and a central brass rod, insulated from the cylinder and connected to one pair of the quadrants of an electrometer.* The needle of the electrometer and the testing cylinder were connected to the negative electrode of a set of dry cells giving a potential difference of 105 volts, the other electrode of the

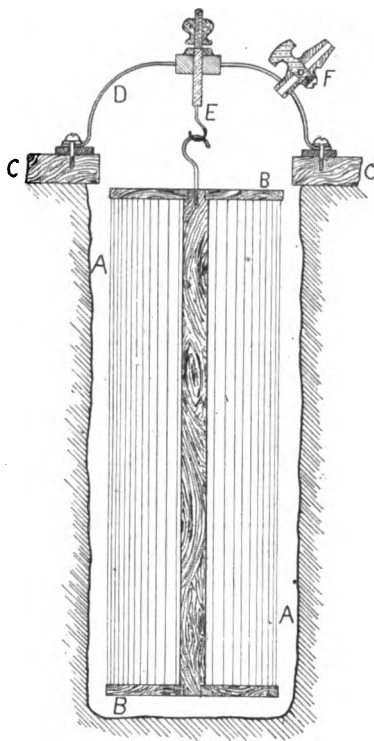


FIG. 1.

* For a description of the electrometer, the testing cylinder and connections, see February (1904) number of this Journal.

battery being to earth. The central rod of the testing condenser and the pair of quadrants it was connected with were earthed ordinarily, but could be insulated at will by pressing a key. The electrometer was very steady throughout the following experiments and had a sensitiveness of 250^{cm} per volt with 100 volts on the needle and the scale at one meter.

The observations were taken in the following manner: The zero position of the needle was observed, then the central rod of the testing vessel and the quadrants it was connected with were insulated. Observations of the ionization current were taken at the end of half a minute, one minute and two minutes

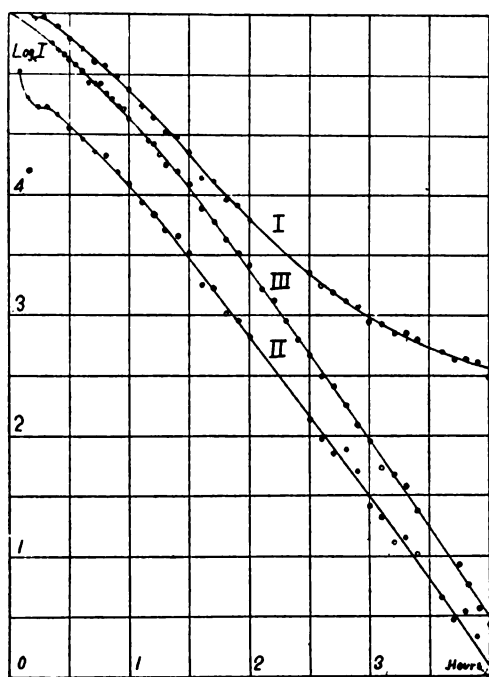


FIG. 2.

after the quadrants and the central rod were insulated; then these were earthed again. This was done at six-minute intervals for five hours, after which the activity of the wire decayed very slowly, and it was not necessary to take observations so frequently. The decay of the activity for the first four hours is given by curve I of figure 2, where the time is plotted as abscissae and the natural logarithms of the ionization currents as ordinates. The experiment was continued for three days,

observations being taken at longer intervals. About five hours after the potential difference was removed from the negatively charged wire, the ionization due to radium excited activity was vanishingly small, all the activity, about five per cent of the total initial activity, being of a very much more slowly decaying type. The rate of decay of this slowly decaying activity was calculated from the data of two experiments; in one case the half-value period was 10 hours and 12 minutes, and in the other case it was 10 hours and 47 minutes, giving an average value of $10\frac{1}{2}$ hours. This is very near the half-value period of thorium excited activity, which is about 11 hours. None of the excited activities of the known radio-active substances or a combination of them can account for the slowly decaying excited activity of ground air, except thorium excited activity.

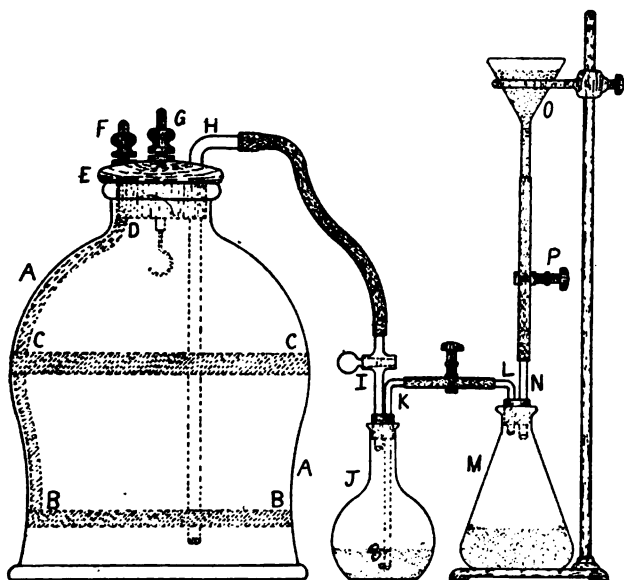


FIG. 3.

It is very improbable that there is an unknown radio-active substance whose excited activity falls to half-value in about the same time as that of thorium. Hence there is no reason to doubt that the slowly decaying activity obtained by exposing a negatively charged wire to underground air is thorium excited activity.

In order to see if the presence in the underground air of radium and thorium emanations was enough to account for the

ground air excited activity, the following experiments were made:

A piece of copper wire, $\frac{1}{4}$ mm in diameter and 2 meters long, was exposed to radium emanation in an apparatus shown in figure 3. The apparatus consists of a glass bell-jar, AA, 22 cm in diameter and 30 cm high. It is fitted with an insulating cap, E, provided with two binding-posts, F and G. The binding-post F is in contact with a strip of tinfoil, DCB, and through that with two other strips of tinfoil, CC and BB, all three being pasted inside the bell-jar. J is a flask containing a solution of radium bromide of 1000 activity, prepared by De Haan. A glass tube, I, provided with a glass stopcock, is connected by a piece of rubber tubing to another tube, H, which passes through the insulating cap, E, into the bell-jar and puts the latter in communication with the flask which contains the radium solution. Another flask, M, is connected with the flask J through two glass tubes, K and L, joined by a piece of rubber tubing carrying a screw pinchcock. Another piece of rubber tubing carrying a screw pinchcock connects a funnel, O, to the flask M.

The wire to be exposed to radium emanation was loosely coiled and was hung from a hook soldered to the lower end of the binding-post G. The latter was connected to the negative electrode of a storage battery of 100 volts, while the binding-post F was connected to the positive electrode of the battery. Thus an electric field was set up within the bell-jar. Then some water was poured into the funnel and the pinchcock, P, was regulated such that the water dropped into the flask M, drop by drop. Each drop displaces an equal volume of air, which bubbles out through the radium solution. This bubble in its turn forces part of the mixture of air and radium emanation in the flask J to go into the bell-jar. Thus the bell-jar is supplied uniformly with radium emanation. This rather elaborate method of exposing the wire to radium emanation was used to guard against particles of radium which might otherwise come into contact with the wire or the bell-jar. After the wire was charged for exactly three hours it was taken out of the bell-jar, was introduced into the testing cylinder and observations of the ionization currents were taken as described above. The results of the experiment are shown by curve III, figure 2.

The rate of decay of thorium excited activity also was taken by exposing a piece of copper wire, of the same dimensions as the one used for radium excited activity, to thorium emanation. The source of the emanation was about 10 grams of powdered thorium oxide, which was spread uniformly over a watch-glass and placed under the bell-jar. The wire was

charged negatively for three hours and the rate of decay of the activity was observed as before. The results of two such experiments are shown by curves I and II, figure 4, where the ordinates represent the ionization currents and the abscissae the time. These curves have half-value periods of about 11 hours and agree very closely with those given by Rutherford.

The component due to thorium of the total ionization of the ground-air excited activity was calculated by a method to be described below, and was subtracted from the latter in order to compare the result and activity with radium excited activity. It is obvious that the resultant activity will be nothing more nor less than radium excited activity provided that the ground-

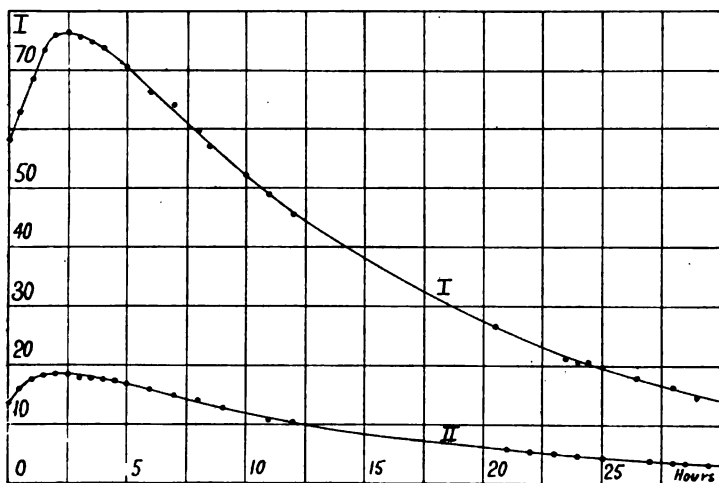


FIG. 4.

air excited activity is composed solely of radium and thorium excited activities. It was shown above that the activity of the negatively charged wire exposed to ground-air was entirely thorium excited activity at the end of five hours after the removal of the potential difference from the wire. Hence the thorium element of the ground-air excited activity at any time can be found by multiplying the ionization of the thorium excited activity, for the corresponding time, by the ratio of the ionizations of the ground-air and thorium excited activities at any time after five hours. The ratio of the ionizations, at the end of nine hours of the ground-air and thorium excited activities, represented by the curves I of figures 2 and 4 respectively, was found to be 0.0216. Each of the observed values of the ordinates of curve I, figure 2, was multiplied by this ratio and

the product was subtracted from the former. The results when plotted gave curve II of the same figure, which represents the rate of decay of the ground-air excited activity minus the part due to thorium. A glance at figure 2 is enough to show the difference both in nature and rate of decay of curves I and III on one hand, and the agreement between the curves II and III on the other. Yet it will be observed that the latter are not exactly parallel; curve II slopes at a little slower rate than curve III. Hence apparently the ground-air excited activity decays at a slightly slower rate than a combination of radium and thorium excited activities, in the same proportion as they occur in the ground-air excited activity. Bumstead has observed a similar disagreement between the rates of decay of the excited activity obtained from atmospheric air and a combination of radium and thorium excited activities.* No attempt will be made in this paper towards explaining the disagreement, as the writer is at present engaged in a series of experiments to that end, the results of which will appear in a later number of this Journal.

In conclusion, I wish to express my thanks to Professor H. A. Bumstead for his kind interest in these experiments and for his valuable suggestions.

Sheffield Scientific School of
Yale University, Nov., 1904.

* Loc. cit. p. 7.

ART. III. — *The Types of Limb-Structure in the Triassic Ichthyosauria*; by JOHN C. MERRIAM.*Introduction.*

OF the numerous valuable contributions to paleontological literature made by the late Professor George Baur, one of the most interesting was that in which he furnished evidence that the limbs of the Jurassic Ichthyosaurs were highly specialized structures developed in adaptation to aquatic life.* In advancing this view he opposed the theory of Gegenbaur and others, who held that they were generalized and intermediate between the pentadactyle limbs of the higher vertebrates and the many-rayed extremities of the selachians. As was shown by Baur, the limbs of the Triassic Ichthyosaurs come nearer to the type of extremity found in the primitive reptilia than do those of the later representatives of the order. The character of the modification of the limbs, and in fact the whole structure of the body in the later Ichthyosaurs, indicated to him that, as a group, they bore the same relation to the Rhynchocephalia that the cetaceans bear to the primitive mammals.

At the time Baur wrote on this subject, the only available Triassic specimens showing the limbs were those from the bituminous shales of Besano in Lombardy. These he separated from *Ichthyosaurus* as a new genus, *Mixosaurus*.

Within the last few years considerable collections obtained from the Triassic of California have brought to light several new groups of Ichthyosaurians differing not a little from the previously known genera of Europe. So many new forms have appeared in this fauna that some of the questions relating to the origin and descent of the Ichthyosauria are reopened. The addition of new material has made the problems more complicated, but it is hoped that before we again reach the limits of profitable discussion it will be possible to add something to our knowledge of the origin and the history of the group.

Characteristics of known types.

At the present time we are acquainted with not less than four types of limbs in the Triassic Ichthyosaurs. One of these is represented in *Mixosaurus*, a second in the genera *Toretocnemus* and *Merriamia*,† a third in *Shastisaurus osmonti* and

* Ueber den Ursprung der Extremitäten der Ichthyoptergia, Ber. d. xx, Versamml. d. oberrhein. geol. Ver., xx, p. 8.

† See G. A. Boulenger, Proc. Zool. Soc. Lon., 1904, vol. i, p. 425. *Leptocheirus* Merriam being preoccupied is replaced by *Merriamia* Boulenger.

alexandrae. The fourth appears in a recently discovered specimen which seems to be specifically identical with *Shastasaurus perrini*. This form evidently represents a genus distinct from the type seen in *S. osmonti* and *alexandrae*, and the name *Delphinosaurus** may be used to distinguish it from the more specialized species.

In *Mirosaurus* (fig. 1) the extremities are of a primitive type. Both manus and pes are pentadactyle,† the elements of the limbs are generally quite slender and in many cases have a median constriction. This form is farther characterized by the articulation of the intermedium distally with two or more elements and by the frequent presence of a fourth element (pisiform) on the posterior end of the proximal row in the mesopodial region.

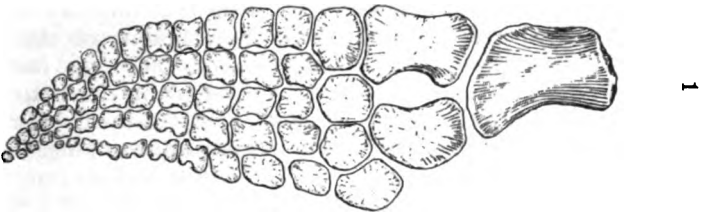
Toretocnemus and *Merriamia* do not differ greatly in limb structure though the vertebrae are of distinct types. In *Merriamia* (fig. 2) the limb has but three digits with the merest vestige of a fourth. There are but three elements in the first row of the mesopodial region and both carpus and tarsus are of a strictly linear type, the intermedium articulating with but a single element distally. In this genus the posterior limbs are much smaller than the anterior. In *Toretocnemus* the posterior limbs equal or exceed the anterior in size and the vestigial fourth digit of the posterior limb appears to have been larger than in *Merriamia*.

The most specialized limb found in the Triassic genera, and one of the most specialized types known in the Ichthyosauria, is seen in *Shastasaurus osmonti* (fig. 4). The anterior limb in this genus is characterized by extreme shortening of all the elements. The humerus is actually as broad as long and is one of the shortest propodial elements known in the reptilia. The epipodial bones are also greatly abbreviated, though separated by a narrow cleft. Of the carpus only the radiale is known. It is as large or larger than the ulna and its margin is entire, while that of the radius shows an anterior notch.

In the recently discovered anterior limb referred to *Delphinosaurus* (*Shastasaurus*) *perrini* (fig. 3) the humerus, radius and ulna are longer than in *S. osmonti*, and the radius and ulna are both deeply constricted. The radiale is narrower and is notched. The carpus is of the linear type and the posterior of the three linear series consists of somewhat smaller bones than are seen in the other two. The elements of the meso-

* *Delphinosaurus* is characterized by much elongated vertebral centra; an unnotched scapula, and the peculiar structure of the limbs described above.

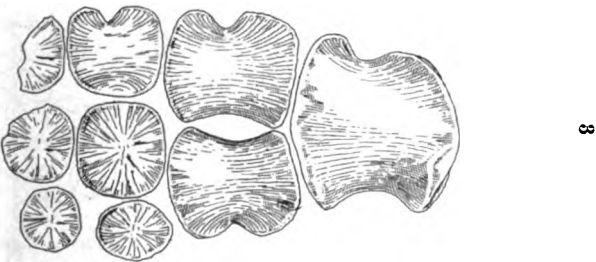
† See redescription of *Mirosaurus*, E. Repossi, Atti. della soc. ital. d. scien. Natur., vol. xli, fasc. 3, p. 361-372, Tav. viii, ix.



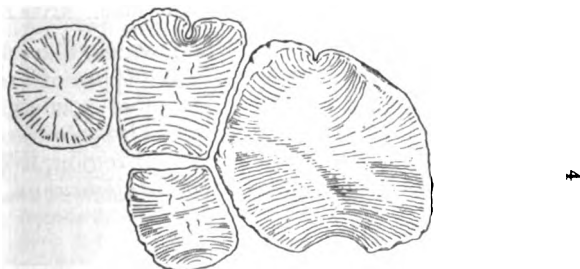
1



2



3



4

Fig. 1.—*Misosaurus cornalianus*. Left anterior limb. $\times \frac{1}{2}$. Slightly modified from Reppesi.

Fig. 2.—*Merrimuta zittelii*. Left anterior limb. $\times \frac{1}{2}$.

Fig. 3.—*Delphinosaurus perrini*. Left anterior limb. $\times \frac{1}{2}$.

Fig. 4.—*Shastasauros osmonti*. Left anterior limb. $\times \frac{1}{2}$.

podial and phalangeal regions, as far as known, are rounded and have deeply excavated borders, showing that they lay in heavy pads of cartilage. Judging from the character of the carpus in *Delphinosaurus* and in *Merriamia*, the large radiale in *S. osmonti* indicates that the anterior digit of the manus was relatively larger and the third smaller in *Shastasaurus* than in the other forms. The limb would in that case be reduced almost to a two-fingered type.

Degree of differentiation.

The degree of differentiation shown in the three or four types of limb structure known in the Triassic Ichthyosaurs

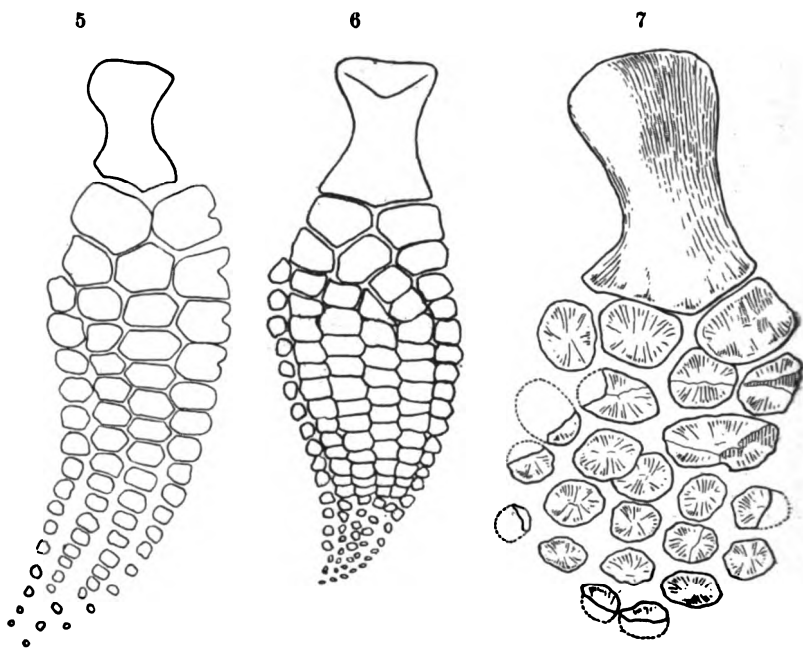


FIG. 5.—*Ichthyosaurus quadricissus*. Anterior limb. $\times \frac{1}{4}$. After Fraas.

FIG. 6.—*Ichthyosaurus conybeari*. Anterior limb. After Lydekker.

FIG. 7.—*Baptanodon marshi*. Anterior limb. After Knight.

appears quite remarkable when we compare it with what we find in the Jurassic genera. Three types of limb structure are known from the Jurassic. The most specialized of these is found in *Baptanodon* (fig. 7) and *Ophthalmosaurus* with three very short elements in the epipodial region, five or more digits, and discoidal phalanges. In *Ichthyosaurus*, possessing two

short epipodial elements, there are two groups. Of these the Longipinnati (fig. 5) have an essentially linear mesopodial region, a notched radius and usually three to five digits. The Latipinnati (fig. 6) have an alternate arrangement of the mesopodial region caused by the articulation of two or more distal elements on the intermedium; there are generally between five and ten digits; and notches are rarely present on the phalanges, while never on the radius. Compared with these three types the Triassic forms show an unexpected degree of differentiation.

Primitive characters.

In spite of the differentiation shown in the Triassic types, they have all retained certain primitive characters not common in the later forms. All show a separation of the radius and ulna, and in all excepting *Shastasaurus osmonti* these elements are elongated and the radius is constricted or shafted. The presence of these and other primitive characters in so many otherwise different forms furnishes us with much stronger evidence of the origin of the Ichthyosauria from generalized shore forms than could have been given by the single type known to Baur.

Lines of descent.

A comparison of the Jurassic and Triassic genera of Ichthyosaurs with a view to determining the lines of descent shows immediately that no known Jurassic form can be considered as having descended from the specialized *Shastasaurus*. So far as we now know, this group disappeared in the Triassic. *Baptanodon* and *Ophthalmosaurus* are also practically excluded from any comparison with the Triassic genera, as they are comparatively late forms and could be derived from the latipinnate Ichthyosaurs as easily as from any of the much older Triassic types.*

The views which we hold concerning the descent of the remaining Jurassic groups involve our interpretation of the homologies of the elements in the Ichthyosaurian paddle. On this subject a considerable variety of opinion has been expressed, particularly with reference to the relationships of the mesopodial elements.

Some years ago Lydekker† suggested that the most generalized type of limb in the Jurassic Ichthyosaurs is found in the

* Dr. O. P. Hay (Bull. 179 U. S. G. S., p. 463) has, I believe inadvertently, placed the West-American Triassic Ichthyosauria under the Baptonodontidae. Based on this suggestion, Boulenger (loc. cit.) has indicated the descent of *Ophthalmosaurus* from *Shastasaurus*. The writer is obliged to regard these groups as probably the most widely separated of all the known Ichthyosauria.

† Geol. Mag., 1888, Decade 8, v, p. 310.

Longipinnati, such as *Ichthyosaurus tenuirostris*. The anterior digit was considered as representing digit II of the primitive limb, digit I having disappeared. Latipinnate forms, such as *I. intermedius*, were supposed to be more specialized, the additional digit in the middle of the hand having been produced by the splitting of digit III. The longipinnate group would then be the more primitive and the latipinnate forms be derived from it by intercalation or splitting of digits.*

Strongly suggestive of the latipinnate and longipinnate paddles we find also in the Triassic genera a broad and a narrow type, the broad form occurring in *Mixosaurus*, the narrow form in all of the Californian genera. In the narrow type the limb is even more reduced than in the Longipinnati and is really tridactyle. So far as can be determined, *Toretocnemus* seems to be the most primitive of these forms. The rudimentary fourth digit is larger than in the others and the third digit is as large as the first. In *Delphinosaurus* the third digit is much smaller than the others and in *Shastasaurus osmonti* it was probably smaller than in *Delphinosaurus*. This series showing progressive reduction of the posterior side of the limb indicates that the type is probably not a primitive one, but is derived from an earlier form with five digits.

While we can understand the origin of the narrow type of paddle in the Trias, the broad form is not so easily explained if we hold that digit number one has disappeared. *Mixosaurus* had five digits of nearly equal size and made up largely of the shafted or primitive type of phalanges. The extremities of this form were, however, *already specialized paddles*, and, if the interpretation of the structure of the paddle of *Ichthyosaurus* given above is correct, we shall have to suppose that in this form digit I was lost and another digit added.

If finger I in *Mixosaurus* corresponds to primitive digit II, the added digit is either below the intermedium or on the posterior border of the limb. The presence of a supernumerary ossicle behind the carpus seems to give support to the idea that the last digit is not primitive, as elements of this character are known to develop secondarily, particularly on the posterior borders of the limbs of aquatic forms. Their presence does not prove the case, however. The supernumerary ossicle may be secondary and the digit primitive, or the presence of the ossicle may be due to upward movement of the last digit along the posterior side of the carpus. Such movements have occurred frequently in Ichthyosaurian paddles, regardless of the theory by which we account for them.

To suppose that one of the digits below the intermedium is

*Mr. Lydekker has recently expressed himself as in accord with the views concerning the primitive character of the Mixosaurian paddle which are presented in this paper. See p. 29.

of secondary origin would seem almost a violent assumption. That splitting and intercalation of digits have occurred in some of the broad-paddled Ichthyosaurs is beyond question, but evidence of the character which we find in these forms is lacking in the paddle of *Mixosaurus*. The digits are of equal size and their relations to the intermedium are such as one might expect to find in a fairly primitive limb.

Though there is a tendency for the short first digit to disappear in the evolution of a natatory limb, it has not always done so, as for example in the Plesiosaurs. Farther, in the history of the Ichthyosauria two quite distinct types of paddles have appeared; the broad form, illustrated in the Latipinnati and in *Mixosaurus*; and the narrow form, represented in the Longipinnati and in the Californian genera. In all probability the course of evolution has in all cases been fairly direct. That is, the broad paddles have tended toward greater width and the narrow ones toward slenderness. It is not easy to imagine that after limbs had been reduced to a narrow type they would again increase in width. There is therefore good reason to believe that *Mixosaurus* and the Latipinnati have retained the first digit.

If the first digit in the limb of *Mixosaurus* represents digit I of a primitive pendactyle form, this type may be considered as the most generalized known in the Ichthyosauria. If, on the other hand, the first digit represents number two of the primitive form, the limb can hardly be considered as less specialized than the tridactyle form seen in *Merriamia*, one form having lost two digits, the other having lost one and gained one. Supporting the first suggestion we have the fact that *Mixosaurus* is the oldest described form in which the limb structure is known. The beds in which it occurs are considered by Fraas as the equivalent of some portion of the Middle Triassic, while the Californian genera belong to the Upper Triassic. Evidently *Mixosaurus* is the only described genus which could be considered as ancestral to the Jurassic forms. In the other genera the reduction of the digits has gone farther than in the Jurassic Longipinnati.

It is not impossible that other forms with wider paddles will be found in the American Trias, but up to the present time only the leptochirous or narrow-paddled group seems to be represented. These forms may be closely related to the Longipinnati or may represent a branch of the order which diverged and specialized early. The Longipinnati and Latipinnati may have developed from a persisting primitive stock after the American Triassic forms had become well separated from the rest of the order.

It should be borne in mind that while the evidence furnished by limb structure is some of the most valuable material that we

can obtain for use in working out the phylogeny of the Ichthyosaurs, it can hardly furnish the whole foundation for a definite classification. Inside the American group there seems to be considerable variation, though as yet we do not know all of the most important characters of these forms. *Toretocnemus* and *Merriamia* have very similar limbs but differ considerably in the structure of the vertebrae and ribs. It is perhaps a significant fact that of the several genera, *Toretocnemus*, with the largest vestigial fourth digit, appears in its general structure to be nearest to some of the earliest forms of Europe, represented by *Ichthyosaurus* (?) *atavus** from the lower portion of the middle Trias.

* Recent comparisons of *Ichthyosaurus* (?) *atavus* with the types of *Mixosaurus* show that most of the known vertebrae of *atavus* are quite different from those of the true *Mixosaurus*. So far as is known, they approach most nearly the type of the true Ichthyosaurs. They may belong to *Ichthyosaurus*, possibly to *Toretocnemus*, or may represent an undescribed genus.

University of California, Berkeley.

ART. IV. — *The Interaction of Hydrochloric Acid and Potassium Permanganate in the Presence of Ferric Chloride*; by JAMES BROWN.

[Contributions from the Kent Chemical Laboratory of Yale University—CXXXII.]

LÖWENTHAL* and LENSSEN were the first to show that the titration of ferrous salts by potassium permanganate in the presence of hydrochloric acid as proposed by Margueritte† does not admit of quantitative accuracy because of the evolution of chlorine by the interaction of hydrochloric acid and potassium permanganate, and to propose as a remedy for this source of error the titration of successive equal portions of the ferrous salt to be determined until the readings become constant.

This tendency toward evolution of chlorine in titrations of a ferrous salt by potassium permanganate in the presence of hydrochloric acid as compared with the alleged absence of such tendency in similar titrations of oxalic acid, was explained by Zimmermann‡ on the supposition that the oxidation of the iron proceeds so rapidly as to form oxides of iron higher than the sesquioxide which then react to oxidize more iron and liberate chlorine from hydrochloric acid. Quite recently Wagner§ explains this phenomenon by the assumed formation of chlor-ferrous acid (analogous to chlor-platinic and chlor-auroic acids), which is more easily oxidized by the permanganate than is hydrochloric acid under similar conditions. Recent work|| has shown that there is a slight though real waste of permanganate in titrations of oxalic acid under the conditions named, and that this loss is proportional to the amount of hydrochloric acid present. It still appears, however, that this loss is greater in titrations of ferrous salts than in those of oxalic acid under the conditions named.

Wagner's work in relation to the phenomenon mentioned above has been reviewed very carefully, and it has been found that, although as shown by him more permanganate is required to bring about final coloration against equal quantities of oxalic acid in experiments in which equal quantities of potassium permanganate are digested with a constant quantity of normal hydrochloric acid and a measured volume of tenth normal ferric chloride than when an equivalent quantity of tenth-normal hydrochloric acid is substituted for the tenth-normal ferric chloride, the differences vary within wide limits and disappear entirely if the chlorine formed by the interaction of the potas-

* *Zeit. Anal. Chem.*, i, 829.

† *Ann. Chim.* [3], xviii, 244.

‡ *Ann. Chem.*, cxiii, 811.

§ *Maassanalytische Studien*, Habilitationsschrift, Leipzig, 1896.

|| Gooch and Peters: *This Journal* [4], vol. vii, 463.

sium permanganate and hydrochloric acid is removed during the digestion. When also the chlorine is thus removed the same quantity of permanganate is required to bring about final coloration whether ferric chloride is present or not. It is found also that the permanganate is entirely destroyed within the limits proposed by Wagner, and that after an hour's digestion, and in fact long before, the permanganate color has entirely disappeared and only the hydrated oxides of manganese, formed according to the Guyard reaction, are visible in the digestion liquid.

Wagner describes no special form of apparatus in his work, and gives no details as to size of flask used to contain the digestion liquids, form of bath, etc., pointing out the fact simply that he used a return-condenser 60^{cm} in length. It was found convenient in the experiments about to be described to use a 250^{cm}³ flask to contain the solutions during digestion, and to heat the solutions in an Ostwald thermostat.

TABLE I.
[9·91^{cm}³ H₂C₂O₄ = 20·25^{cm}³ KMnO₄]

N 1 HCl cm ³ .	N 10 HCl cm ³ .	N 10 FeCl ₃ cm ³ .	KMnO ₄ before dige- stion. cm ³ .	Tem- pera- ture C°.	Time dige- stion. min.	N 10 H ₂ C ₂ O ₄ cm ³ .	KMnO ₄ to color. cm ³ .	KMnO ₄ apparently reduced during dige- stion. cm ³ .
100	9·91	---	9·91	50	60	9·91	15·89	5·55
100	9·91	---	9·91	"	"	9·91	15·11	4·77
100	9·91	---	9·91	"	"	9·91	15·15	4·81
100	9·91	---	9·91	"	"	9·91	15·07	4·73
100	9·91	---	9·91	"	"	9·91	15·18	4·79
100	9·91	---	9·91	"	"	9·91	15·07	4·73
100	9·91	---	9·91	"	"	9·91	15·08	4·74
100	9·91	---	9·91	"	"	9·91	15·02	4·68
100	9·91	---	9·91	"	"	9·91	14·85	4·51
100	9·91	---	9·91	"	"	9·91	14·40	4·06
100	9·91	---	9·91	"	"	9·91	15·05	4·71
100	---	9·91	9·91	"	"	9·91	15·60	5·26
100	---	9·91	9·91	"	"	9·91	15·35	5·01
100	---	9·91	9·91	"	"	9·91	15·32	4·98
100	---	9·91	9·91	"	"	9·91	15·88	5·54
100	---	9·91	9·91	"	"	9·91	15·42	5·08
100	---	9·91	9·91	"	"	9·91	15·45	5·11
100	---	9·91	9·91	"	"	9·91	15·95	5·61
100	---	9·91	9·91	"	"	9·91	15·41	5·07
100	---	9·91	9·91	"	"	9·91	15·95	5·61
100	---	9·91	9·91	"	"	9·91	16·65	6·31
100	---	9·91	9·91	"	"	9·91	15·75	5·41
100	---	9·91	9·91	"	"	9·91	15·79	5·45

The experiments of Table I were conducted, as outlined by Wagner, in the following manner: To a 250^{cm}³ flask were added 100^{cm}³ of normal hydrochloric acid (that is a solution contain-

ing 36.4575 grams of the acid to the liter), and in addition either 9.91^{cm³} of tenth normal hydrochloric acid (prepared by diluting 100^{cm³} of the normal solution to one liter) or 9.91^{cm³} of tenth normal ferric chloride. Of approximately twentieth normal potassium permanganate, carefully standardized against ammonium oxalate, 9.91^{cm³} were then added, and the flask, fitted in a ground joint to a return-condenser 60^{cm} in length and with a bore approximately 3^{cm} in diameter, was heated for one hour in the Ostwald thermostat at a temperature of 50° C. Of tenth normal oxalic acid, 9.91^{cm³} were then added to the digestion liquid and a measured volume of the same permanganate solution as was added before digestion was run in to color. The difference between the total permanganate used (that is the permanganate added before digestion plus that added to bring about final coloration against the oxalic acid) and the permanganate equivalent of the oxalic acid added gives, according to Wagner, the permanganate reduced during the digestion. The results of these experiments are recorded in the above table.

Here it may be seen that although in general more permanganate is required to bring about final coloration in those experiments in which ferric chloride was used than in its absence, the results show at best wide variation among themselves, and the amounts of permanganate apparently destroyed during the digestion are at all events considerably greater than in the experiments conducted by Wagner under similar conditions. In the experiments recorded in Table I, in the average 4.73^{cm³} of permanganate were apparently destroyed where ferric chloride was not used, and 5.37^{cm³} in the presence of ferric chloride; while in Wagner's experiments 0.96^{cm³} of permanganate was apparently reduced without use of ferric chloride and 1.41^{cm³} in its presence.

Since, as has been noted above, the permanganate color entirely disappeared in the experiments of Table I, long before the termination of the hour's digestion, while only small amounts of hydrated oxides of manganese varying in color from brown to black were visible in the digestion liquid, it seemed probable that more permanganate was really reduced during the digestion than is indicated in these experiments. Moreover a strong odor of chlorine was noticeable in these experiments and it seemed probable that some of the chlorine, formed by the interaction of the potassium permanganate and hydrochloric acid during the digestion, remained to take part in the oxidation of the oxalic acid introduced, and that, therefore, on running in permanganate solution to color, less of the latter was required than corresponded to the oxalic acid left unoxidized by the residual oxides of manganese. It was, therefore, decided to

remove if possible this chlorine, and to this end a vigorous current of carbon dioxide or air was passed through the digestion liquid while heating. In this way the chlorine was readily removed and starch and potassium iodide paper held in the current of carbon dioxide or air gave no test for chlorine.

The experiments of the following table (II), in which no ferric chloride was used, were conducted precisely as were those of Table I above, except that a vigorous current of carbon dioxide generated in a Kipp generator by action of hydrochloric acid on marble, and washed and dried by passing first through a bottle filled with water and then through a calcium chloride tube, was passed through the liquid during the process of digestion. Because also of the greater ease of measuring out accurately 9.90^{cm³} rather than the 9.91^{cm³} used by Wagner and in the experiments of Table I above, the former volume of reagents was substituted for the latter in the experiments to follow. It will readily be seen that in the case of tenth normal hydrochloric acid 0.01^{cm³} is negligible as compared with the large amount of hydrochloric acid used in the experiments.

The results of these experiments are recorded in Table II.

TABLE II.

	N 1 HCl cm³.	N 10 HCl cm³.	KMnO ₄ before diges- tion. cm³.	Tem- pera- ture. C°.	Time of diges- tion. min.	H ₂ C ₂ O ₄ cm³.	KMnO ₄ to color cm³	KMnO ₄ apparent- ly reduced during digestion. cm³.
[9.90 ^{cm³} approximately $\frac{N}{10}$ H ₂ C ₂ O ₄ = 23.52 ^{cm³} KMnO ₄]								
I	100	9.90	9.90	50	60	9.90	22.19	8.57
II	100	9.90	9.90	"	"	9.90	22.10	8.48
III	100	9.90	9.90	"	"	9.90	22.15	8.53
IV	100	9.90	9.90	"	"	9.90	22.11	8.49
[9.90 ^{cm³} approximately $\frac{N}{10}$ H ₂ C ₂ O ₄ = 23.65 ^{cm³} KMnO ₄]								
V	100	9.90	9.90	50	60	9.90	22.15	8.40
VI	100	9.90	9.90	"	"	9.90	21.79	8.04
VII	100	9.90	9.90	"	"	9.90	22.24	8.49
VIII	100	9.90	9.90	"	"	9.90	22.21	8.46
IX	100	9.90	9.90	"	"	9.90	22.24	8.49
X	100	9.90	9.90	"	"	9.90	22.23	8.48
XI	100	9.90	9.90	"	"	9.90	22.25	8.50
XII	100	9.90	9.90	"	"	9.90	22.15	8.40
XIII	100	9.90	19.90	"	"	9.90	19.77	15.92
XIV	100	9.90	19.80	"	"	9.90	19.88	15.98
XV	100	9.90	50.0	"	"	25.00	44.58	34.81
XVI	100	9.90	50.0	"	"	25.00	44.47	34.75
XVII	100	9.90	50.0	"	"	25.00	44.44	34.72
XVIII	100	9.90	50.0	"	"	25.00	44.58	34.86

From these results the conclusion may be drawn that the low indications of the amount of permanganate apparently reduced during digestion in the experiments recorded in Table I, at least so far as concerns those experiments in which no ferric chloride was used, were in all probability due to the oxidizing action of the unexpelled chlorine on the oxalic acid, and that the large variations in results were due to the greater or less retention of the chlorine. In experiments XIII to XVIII it is seen further that amounts of permanganate very much greater than those used in Wagner's experiments and in the experiments of Table I above can be reduced by the same amount of hydrochloric acid, and under the same conditions of temperature and time as in those other experiments; for, in these last experiments, also, the permanganate color entirely disappeared during the digestion.

In order to ascertain if a current of air is equally as effective in removing the chlorine as is carbon dioxide, and also because of the greater availability of the former, the experiments recorded in Table III were conducted in a manner identical with those of Table II, except that a current of air dried and purified was substituted for the carbon dioxide. When also the success of the air current was apparent, ferric chloride was again used and the effect noted.

Results are outlined in the following table.

TABLE III.
[9.90^{cm³} approximately $\frac{N}{10}$ H₂C₂O₄ = 20.09^{cm³} KMnO₄.]

	$\frac{N}{1}$ HCl cm ³ .	$\frac{N}{10}$ HCl cm ³ .	$\frac{N}{10}$ FeCl ₃ cm ³ .	KMnO ₄ before diges- tion. cm ³ .	Tem- pera- ture. C°.	Time of diges- tion. min.	Residual KMnO ₄ color after diges- tion.	Cl Test after diges- tion.	H ₂ C ₂ O ₄ cm ³ .	KMnO ₄ to color. cm ³ .	KMnO apparently reduced during dige- stion. cm ³ .
I	100	9.90	---	9.90	50	60	none	none	9.90	18.88	8.69
II	100	9.90	---	9.90	"	"	"	"	9.90	18.87	8.68
III	100	9.90	---	9.90	"	"	"	"	9.90	18.80	8.61
IV	100	9.90	---	9.90	"	"	"	"	9.90	18.81	8.62
V	100	9.90	---	9.90	"	"	"	"	9.90	18.80	8.61
VI	100	9.90	---	9.90	"	"	"	"	9.90	18.82	8.63
VII	100	9.90	---	9.90	"	30	"	"	9.90	18.77	8.58
VIII	100	9.90	---	9.90	"	"	"	doubtful	9.90	18.70	8.51
IX	100	9.90	---	9.90	"	15	"	very faint	9.90	18.70	8.51
X	100	9.90	---	9.90	"	"	"	"	9.90	18.68	8.49
XI	100	---	9.90	9.90	"	60	"	none	9.90	18.87	8.68
XII	100	---	9.90	9.90	"	"	"	"	9.90	18.85	8.66
XIII	100	---	9.90	9.90	"	"	"	"	9.90	18.81	8.62
XIV	100	---	9.90	9.90	"	"	"	"	9.90	18.81	8.62
XV	100	---	9.90	9.90	"	"	"	"	9.90	18.87	8.68
XVI	100	---	9.90	9.90	"	"	"	"	9.90	18.85	8.66
XVII	100	---	9.90	9.90	"	30	"	"	9.90	18.80	8.61
XVIII	100	---	9.90	9.90	"	"	"	doubtful	9.90	18.72	8.53
XIX	100	---	9.90	9.90	"	15	"	very faint	9.90	18.65	8.46
XX	100	---	9.90	9.90	"	"	"	"	9.90	18.67	8.48

Here again may be noted the concordance of results when the chlorine is all removed before the addition of oxalic acid, as well as the fact that under these conditions substantially the same amount of permanganate is required to bring about the end reaction, whether ferric chloride is present or not; and that consequently as much permanganate is reduced during the digestion in the latter case as in the former. Also by a comparison of experiments VIII-X and XVIII-XX, in which a slight trace of chlorine remained, with experiments I-VI and XI-XVI, in which the chlorine was entirely removed, we again see the oxidizing effect of the residual chlorine on the oxalic acid; for even in the former sets of experiments, in which the digestion was carried on only fifteen or thirty minutes, the permanganate color had entirely disappeared at the end of the digestion. The variations in the amount of permanganate apparently reduced during the digestion in the experiments recorded in Table I are, therefore, doubtless due to the interfering action of the residual chlorine held in solution. The "KMnO₄ apparently reduced during digestion" in the experiments of Table II, and in those of Table III in which the chlorine was entirely removed during the digestion, represents the amounts of permanganate entirely reduced to manganous chloride, while the differences between these amounts and the "KMnO₄ before digestion" represent the residual oxides of manganese. Similar differences in the experiments of Table I, and in those of Table III in which the chlorine was only partially removed, represent the residual oxides of manganese and the chlorine retained in solution.

The amount of chlorine held in solution when no means are employed to remove it, depends largely on the form and size of the flask used to contain the solutions during digestion, also on the dimensions of the return-condenser, and will vary according to the greater or less amount of shaking to which the flask is subjected during the entire course of the experiment. It is, therefore, evident that Wagner's experiments are in no way indicative of the relative amounts of potassium permanganate reduced in the presence or absence of ferric chloride other conditions being constant, but are an indication simply of the greater or less retention of chlorine in solution in the form of apparatus used by him; for it has been shown that in all experiments conducted within the limits proposed by Wagner the permanganate is entirely destroyed and that any variations in the amount of permanganate apparently destroyed during digestion disappear when the chlorine is entirely removed from the sphere of action. The possibility of any interfering action of ferric chloride in titrations of oxalic acid by potassium permanganate is excluded by the results of the experiments of

Table III, in which we find no variations in results whether ferric chloride is present or not. The cause of the apparently greater destruction of potassium permanganate in those experiments of Table I in which ferric chloride was used than in those in which ferric chloride was not used, is now under investigation.

TABLE IV.

	$\frac{N}{1}$ HCl cm ³ .	$\frac{N}{10}$ HCl cm ³ .	KMnO ₄ before diges- tion. cm ³ .	H ₂ O cm ³ .	Vol- ume during diges- tion. cm ³ .	Tem- pera- ture. C°.	Time of diges- tion min.	Residual KMnO ₄ color after diges- tion.	Cl test after diges- tion.	H ₂ C ₂ O ₄ cm ³ .	KMnO ₄ to color. cm ³ .	KMnO ₄ apparently re- duced during digestion. cm ³ .
$\left[40\text{cm}^3 \frac{N}{10} (\text{H}_4\text{N})_2\text{C}_2\text{O}_4 = 37.64\text{cm}^3 \text{KMnO}_4\right.$ $\left.100\text{cm}^3 \text{H}_2\text{C}_2\text{O}_4 = 101.40\text{cm}^3 \text{KMnO}_4\right]$												
I	100	9.90	100	--	210	50	60	none	faint	100	59.52	58.12
II	100	9.90	100	--	210	"	"	"	"	100	58.44	57.04
$\left[40\text{cm}^3 \frac{N}{10} (\text{H}_4\text{N})_2\text{C}_2\text{O}_4 = 18.35\text{cm}^3 \text{KMnO}_4\right.$ $\left.50\text{cm}^3 \frac{N}{5} \text{H}_2\text{C}_2\text{O}_4 = 49.26\text{cm}^3 \text{KMnO}_4\right]$												
III	100	9.90	50	--	160	50	60	none	none	50	30.72	31.46
IV	100	9.90	50	--	160	"	"	"	"	50	30.75	31.49
V	100	9.90	50	--	160	"	"	"	"	50	30.76	31.50
VI	100	9.90	50	--	160	"	"	"	"	50	30.78	31.52
VII	100	9.90	50	--	160	"	"	"	"	50	30.88	31.62
VIII	100	9.90	50	50	210	"	"	faint	faint	50	27.11	27.85
IX	100	9.90	50	50	210	"	"	"	"	50	27.92	28.66
X	100	9.90	50	50	210	"	"	"	"	50	28.52	29.26
XI	100	9.90	50	50	210	"	"	"	"	50	28.54	29.28
XII	100	9.90	50	50	210	"	"	"	"	50	29.14	29.88
XIII	100	9.90	50	50	210	"	"	"	"	50	28.98	29.72
XIV	100	9.90	50	50	210	"	"	"	"	50	28.56	29.30
XV	100	9.90	50	50	210	"	"	"	"	50	29.96	30.70
XVI	100	9.90	50	50	210	"	85	none	very faint	50	29.96	30.70
XVII	100	9.90	50	50	210	"	60	faint	faint	50	30.22	30.96
XVIII	100	9.90	75	--	185	"	"	none	marked	50	20.72	46.46
XIX	100	9.90	50	50	210	"	120	none	none	50	30.31	31.05
XX	100	9.90	100	--	210	"	60	marked	marked	60	19.58	60.47
XXI	100	9.90	75	50	235	"	220	none	faint	50	21.84	47.58
XXII	100	9.90	100	50	260	"	180	marked	marked	60	10.18	51.07
$\frac{2N}{1} \text{HCl}$												
XXIII	50	9.90	50	--	110	"	60	none	faint	50	30.23	30.97
XXIV	50	9.90	75	--	135	"	60	"	marked	--	--	--
XXV	50	9.90	75	--	135	"	60	"	"	50	30.69	56.43

Since in all experiments thus far conducted the permanganate color has been entirely destroyed, the experiments of Table IV

were made to ascertain if possible how much permanganate can be destroyed by the amount of hydrochloric acid used in the experiments of Table I, II, and III, under the same conditions of time and temperature, and also during greater periods of time. It will readily be seen from the evident oxidation of oxalic acid by chlorine in previous experiments that an exact measure of the maximum amount of permanganate reduction during a given period of time can be obtained only when all the chlorine is removed and at the same time the permanganate color just disappears—a condition difficult to attain. The results recorded in Table IV should therefore be regarded as approximate only.

Thus it may be seen that the same amount of hydrochloric acid as was used in the experiments of Table I, II, and III is capable of breaking down approximately thirty times as much permanganate as was used in those experiments and in the experiments of Wagner, conditions of time and temperature being the same. Changes of volume are of course involved in the use of varying amounts of permanganate but an increase in volume would in all probability be attended by a decrease in the relative amount of permanganate reduced by a constant quantity of hydrochloric acid. In any case the results show a more extensive reduction than is indicated in Wagner's experiments and in those of Tables I, II, and III above.

The conclusion must be drawn, then, that Wagner's experiments in no way show the catalytic effect of ferric chloride in the interaction between hydrochloric acid and potassium permanganate, nor do they furnish evidence in support of the assumed formation of chlor-ferrons acid. They afford simply an indication of the greater or less retention of chlorine in solution, and the greater or less oxidizing action of this chlorine on the oxalic acid in the presence or absence of ferric chloride.

The author is indebted to Prof. F. A. Gooch for much advice and assistance in the preparation of this paper.

ART. V.—On Crystal Drawing; by S. L. PENFIELD.

Introduction.—The methods commonly employed for representing crystals consist in drawing their edges as they appear when projected upon a plane. A peculiarity of the methods used is that the eye, or point of vision, is regarded as being at an infinite distance from the object, so that all edges which are parallel on a crystal appear as parallel lines in the drawing. Thus true perspective, whereby parallel edges would appear in a drawing as lines approaching one another in the distance, is lost sight of. Furthermore, two kinds of projection are employed: *orthographic*, where the lines of projection fall at right angles, and *clinographic*, where they fall at an oblique angle on the plane upon which the drawing is made. Most of the figures found in works on mineralogy and crystallography are drawn in clinographic projection.

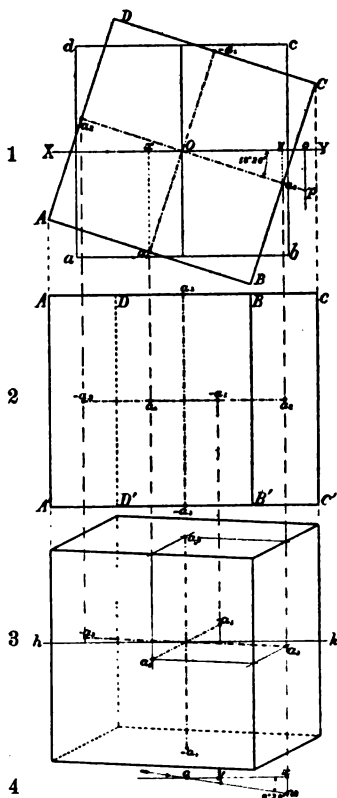
The data generally employed in constructing a crystal figure are the inclinations and lengths of the axes and the symbols of the forms, while interfacial angles are not made use of directly, other than as they may have been employed for determining the axial relations and the symbols of the several faces.

To be really successful in drawing, it is essential that one should have a thorough understanding of the form or combination to be represented, and that every step in the process of constructing a figure should be fully comprehended. The reason for offering the present communication is the hope entertained by the writer, that by developing the subject of crystal drawing in a manner somewhat different from that generally adopted, the processes involved may be comprehended more readily and the work accomplished with greater facility and accuracy.

Projection of the Axes of the Isometric System.—It is believed that figures 1 to 4 will make clear the principles upon which the projection of the isometric axes are based. Figure 1 is an orthographic projection (a *plan*, as seen from above) of a cube in two positions, one, $abc d$, in what may be called normal position, the other, $ABCD$, after a revolution of $18^{\circ} 26'$ about its vertical axis. The broken-dashed lines throughout represent the axes. Figure 2 is likewise an orthographic projection of a cube in the position $ABCD$ of figure 1, when viewed from in front, the eye or point of vision being on a level with the crystal. In the position chosen, the apparent width of the side face $BCB' C'$ is one-third that of the front face $ABA' B'$, this being dependent upon the angle of revolution $18^{\circ} 26'$, the tangent of which is equal to $\frac{1}{3}$. To

construct the angle $18^{\circ}26'$, draw a perpendicular at any point on the horizontal line, as at o figure 1, make op equal one-third Oo , and join O and p . The next step in the construction is a change from orthographic to clinographic projection. In order to give figures the appearance of solidity it is supposed that the eye or point of vision is raised, so that one looks

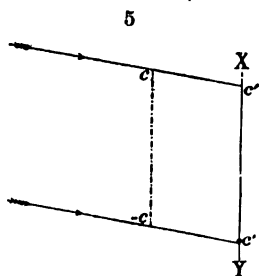
down at an angle upon a crystal which is figured; thus, in the case under consideration, figure 3, the top face of the cube comes into view. The position of the crystal, however, is not changed, and the plane upon which the projection is made remains vertical. From figure 1 it may be seen that the positive ends of the axes a , and a , are forward of the line XY , the distances a , x and a , y being as 3:1. In figure 2 it must be imagined, and by the aid of a model it may easily be seen, that the extremities of these same axes are to the front of an imaginary vertical plane (the projection of XY above) passing through the center of the crystal, the distance being the same as a , x and a , y of the plan. In figure 4 the distance ax is drawn of the same length as a , x of the plan, and the amount to which it is supposed that the eye is raised, indicated by the arrow, is such that a , instead of being projected horizontally to x , is projected at an inclination of $9^{\circ}28'$ from the horizontal to w , the distance xw being one-sixth of ax ; hence the angle $9^{\circ}28'$ is such that its tangent is $\frac{1}{6}$.



FIGS. 1-4.—Development of the axes of the isometric system in orthographic and clinographic projection.

Looking down upon a solid at an angle, and still making the projection on a vertical plane, may be designated as *clinographic projection*; accordingly, to plot the axes of a cube in clinographic projection in conformity with figures 1, 2 and 4, draw the horizontal construction line hk , figure 3, and cross it by four perpendiculars in vertical alignment with the points a , $-a$, and a , $-a$, of figures 1 and 2. Then determine the

extremities of the first, $a_1, -a_1$ axis by laying off distances equal to xw of figure 4, or one-sixth a_1, x of figure 1, locating them below and above the horizontal line hk . The line $a_1, -a_1$ is thus the projection of the first, or front-to-back axis. In like manner determine the extremities of the second axis, $a_2, -a_2$, by laying off distances equal to one-third xw of figure 4, or one-sixth a_1, y of figure 1, plotted below and above the line hk . The line $a_2, -a_2$ is thus the projection of the second, or right-to-left axis. It is important to keep in mind that in clinographic projection there is no foreshortening of vertical distances. This is evident from figure 5, where $c, -c$ is supposed to represent a vertical axis and XY the trace of a vertical plane on which the projection is made. The parallel lines of sight, indicated by the arrows, project the axis $c, -c$ to $c', -c'$ without change of length. In figure 3 the axis $a_3, -a_3$ is somewhat, and $a_1, -a_1$ much foreshortened, yet both represent axes of the same length as the vertical, $a_3, -a_3$, and of the plan above, when plotted in clinographic projection. The completion of the cube about the clinographic axes, as indicated by the construction lines, figure 3, is too simple to need special comment.



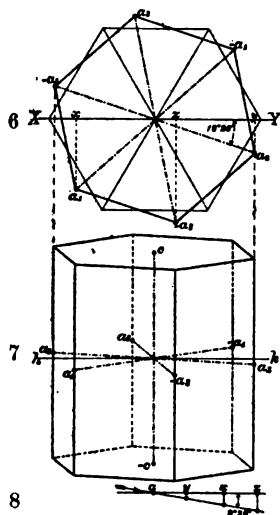
It is wholly a matter of choice that the angle of revolution shown in figure 1 is $18^\circ 26'$, and that the eye is raised so as to look down upon a crystal at an angle of $9^\circ 28'$ from the horizontal, as indicated by figure 4. Also it is evident that these angles may be varied to suit any special requirement. As a matter of fact, however, the angles $18^\circ 26'$ and $9^\circ 28'$ have been well chosen and are established by long usage, and practically all of the figures in clinographic projection, found in modern treatises on crystallography and mineralogy, have been drawn in accordance with them. The development of the axes as indicated by figures 1 to 4 yields the same result as that obtained from following the scheme found in almost all textbooks of crystallography, accredited to Naumann.*

It will be observed that figures 1 and 3 are in vertical alignment, and one of the chief features of this communication will be to emphasize the value and importance of two projections, orthographic and clinographic. The object of the upper figure or *plan* is twofold: (1) it may be employed as a help in the construction of the more complex clinographic projection below, and (2) it serves to make clear certain relations which

* Lehrbuch der Krystallographie, 1830, Band II, p. 400.

at times are only with difficulty, if at all, comprehended from a clinographic projection alone. Figures 2 and 4 have been introduced merely as helps in the development of the clinographic projection. It is also worthy of note that in the majority of cases a plan and its accompanying clinographic projection may be drawn more readily than a single figure in clinographic projection alone.

No originality is claimed for the idea of making use of a plan in connection with a clinographic projection. The principles are those commonly made use of in mechanical drawing, though generally in dealing with that subject orthographic projection alone is employed. In Kokscharow's *Atlas* accompanying his "*Mineralogie Russlands*" it will be found that a plan accompanies almost every figure drawn in clinographic projection, while Miller in his "*Treatise on Mineralogy*" employs orthographic projection almost exclusively. Lastly, students of crystallography may use an orthographic and its accompanying clinographic projection much as a carpenter or builder uses a plan and its accompanying elevation. The one supplements the other.

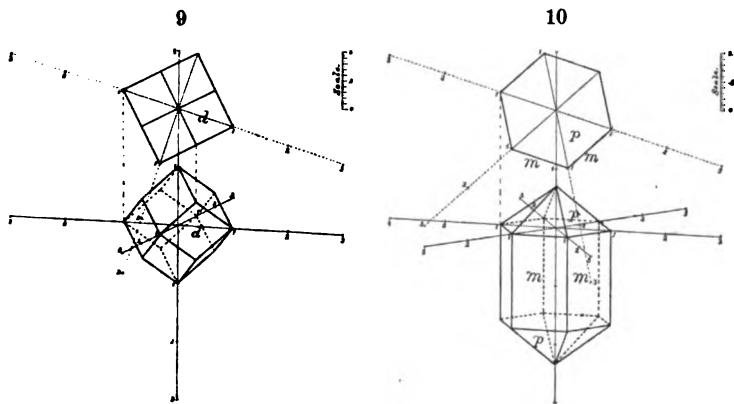


FIGS. 6, 7 and 8.—Development of the axes of the hexagonal system in orthographic and clinographic projection.

Figure 6 is an orthographic projection, a plan, of a hexagonal prism in two positions, one of them, a_1, a_2 , etc., after a revolution of $18^\circ 26'$ from what may be called normal position. In figure 7 the extremities of the horizontal axes of figure 6 have been projected down upon the horizontal construction line hk , and a_1, a_2 and $-a_2$ which are forward of the line XY in figure 6 are located below the line hk in the clinographic projection, the distances from hk being one-sixth of a_1x, a_2y and $-a_2z$ of figure 6. Figure 8 is a scheme for getting the distances which the extremities of the axes are dropped. The vertical axis in figure 7 has been given the same length as the axes of the plan.

Projection of the Axes of the Hexagonal System.—For projecting the hexagonal axes exactly the same principles may be made use of as were employed in the construction of the isometric axes. Figure 6 is an orthographic projection, a plan, of a hexagonal prism in two positions, one of them, a_1, a_2 , etc., after a revolution of $18^\circ 26'$ from what may be called normal position. In figure 7 the extremities of the horizontal axes of figure 6 have been projected down upon the horizontal construction line hk , and a_1, a_2 and $-a_2$ which are forward of the line XY in figure 6 are located below the line hk in the clinographic projection, the distances from hk being one-sixth of a_1x, a_2y and $-a_2z$ of figure 6. Figure 8 is a scheme for getting the distances which the extremities of the axes are dropped. The vertical axis in figure 7 has been given the same length as the axes of the plan.

Engraved Axes.—For the purpose of facilitating crystal drawing the writer has had the isometric and hexagonal axes engraved, and impressions of them made on good quality of drawing paper have been found very useful. To insure accuracy they were plotted on a large scale (the vertical axis 28^{cm} in length) and they are shown very much reduced in figures 9 and 10. Each axis from the center is divided into thirds, and generally the lengths marked 1, when taken as *unity*, will give a figure of convenient size for drawing. In figure 9 an orthographic and a clinographic projection of a dodecahedron are shown, and in figure 10 corresponding projections of a combination of prism *m* and pyramid *p* of apatite, $c = 0.735$. As is evident from the figures, the upper axes are for orthographic,



FIGS. 9 and 10.—Scheme of the engraved axes of the isometric and hexagonal systems, one-sixth natural size.

the lower for clinographic projections. The sections of the axes marked 2 and 3 are lengths most frequently needed in the construction of complex figures. Printed on each sheet is a scale which will be referred to as the *scale of decimal parts*. Its length is equal to that of *unity* on both the vertical axis and the axes for orthographic projection. As printed on the original sheets the scale is divided into one hundred parts.

Axes of the Tetragonal and Orthorhombic Systems.—For drawing tetragonal and orthorhombic crystals the engraved isometric axes may be used, after changing certain lengths. The vertical axis for both systems is changed by taking the desired length from the scale of decimal parts, referred to in the previous paragraph. For an orthorhombic crystal the length of the brachy, or \bar{a} , axis is first laid off on the front-to-

back axis of the orthographic projection above by means of the scale of decimal parts, and is then projected down upon the front-to-back axis below by means of a vertical line. Thus with facility and accuracy the engraved isometric axes may be modified to suit the requirements of any tetragonal or orthorhombic crystal.

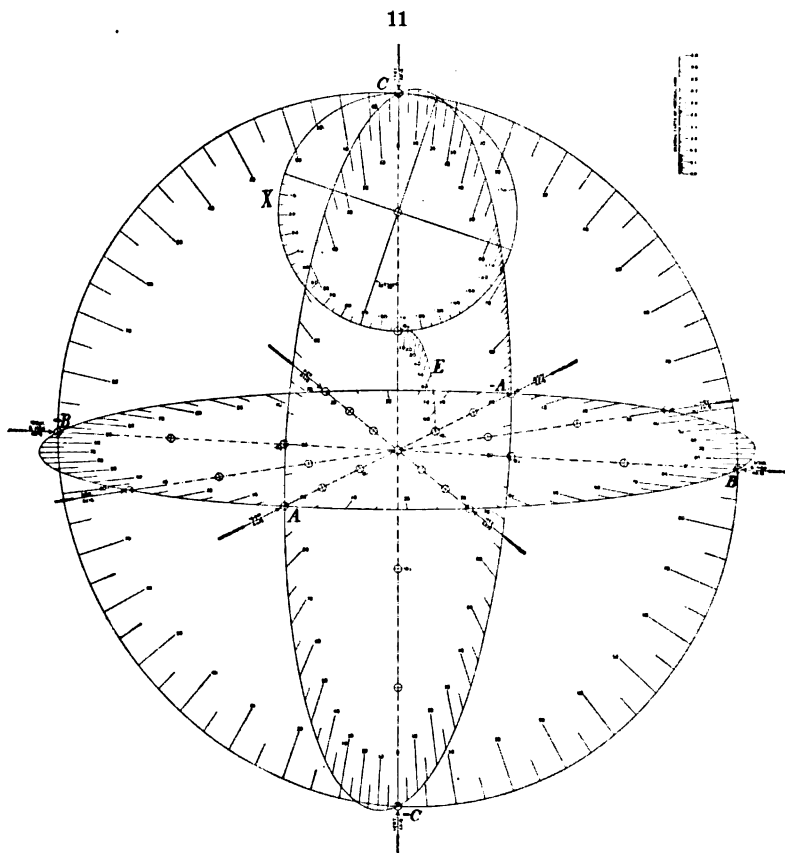


FIG. 11.—Protractor for plotting crystallographic axes; one-third natural size.

Projection of the Axes of the Monoclinic and Triclinic Systems.—These axes are obtained from those of the isometric system by giving the lines suitable inclinations, and varying their lengths. Instead, however, of using the methods generally employed for inclining the axes, it occurred to the writer

that both time and accuracy might be gained by constructing a suitable protractor, which is shown one-third its natural size in figure 11. At the top is a graduated circle, X , two of the diameters of which inclined at $18^{\circ} 26'$ to the vertical and horizontal, represent unit lengths of the a and b axes in orthographic projection. The uses of the circle and its graduation will be explained later. The three large ellipses are the clinographic projections of three circles uniting the ends of the isometric $A, -A; B, -B$ and $C, -C$ axes; they represent, therefore, the paths which the extremities of the axes would follow if the latter were revolved in the three axial planes. The ellipses may also be regarded as the clinographic projection of three great circles of a sphere; an equator, crossed by two meridians at 90° to one another. The ellipses and their graduation were plotted with much care, and the engraving was skillfully executed by Messrs. Bormay & Co. of New York. Each axis is divided into thirds, and a scale giving decimal parts of the vertical axis accompanies the protractor. The quadrant of a small ellipse E has a radius equal to one-third that of the large ellipse. It is intended for getting one-third the length of an inclined a axis, but it has not proved to be of much value. Printed on cardboard, the protractor may be used for a long time, it being intended that the axes shall be transferred to a sheet of drawing paper by superimposing the protractor and puncturing the unit lengths of the axes with a needle point.

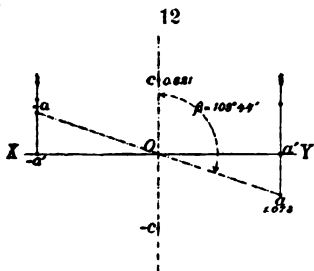
The axial protractor has been in use in the writer's laboratory for four years, and has been found very convenient, not only for plotting axes of the monoclinic and triclinic systems, but, also, for constructing the axes of twin crystals. It may be said of the protractor and also of the engraved axes that they have proved to be not only time-savers, but they have also helped to make the work of crystal drawing more accurate and better understood. Students frequently encounter difficulties in crystal drawing because the axes with which they are working have not been plotted with accuracy, but by the use of the engraved axes this difficulty, at least, is eliminated.

A few examples will serve to illustrate the methods of using the axial protractor in plotting inclined axes.

In both the monoclinic and triclinic systems the same method is used for plotting the a axis at the inclination β , hence one example in the triclinic system will serve for the two classes of crystals. The example chosen is rhodonite, and the data needed are as follows:

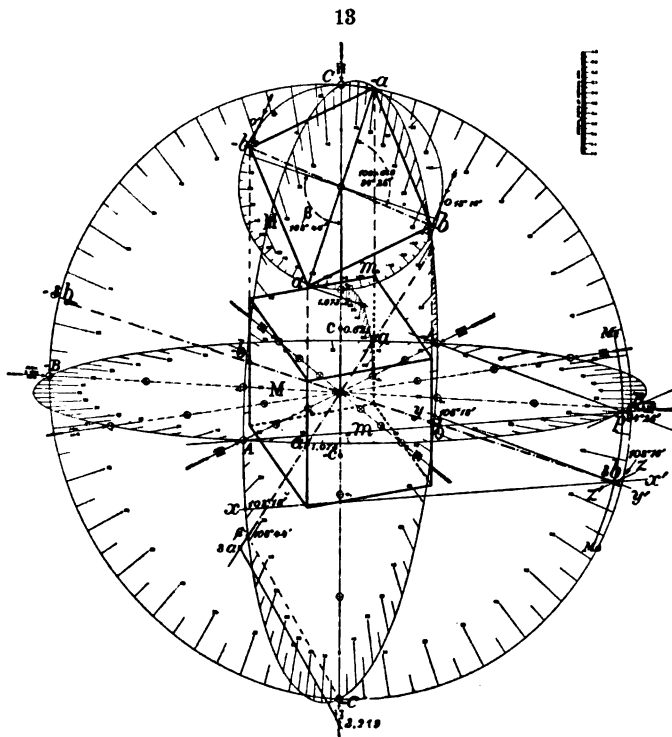
$$\begin{aligned} a : b : c &= 1.073 : 1 : 0.621 \\ a &= 103^{\circ} 18'; \beta = 108^{\circ} 44'. \\ a \wedge b, 100 \wedge 010 &= 94^{\circ} 26'. \end{aligned}$$

The projection of the a axis, which is the same for both the monoclinic and triclinic systems, will first be explained: When a is not at right angles to c , it must appear somewhat



foreshortened in orthographic projection, as shown in figure 12, which represents the relations of the a and c axes of rhodonite: XY being the trace of the horizontal plane on which the orthographic projection is made, the a axis, length 1.073, will appear foreshortened to the length Oa' . Applying the foregoing principle

to the upper circle of the protractor, figure 13, draw a radius at the inclination β , $108^\circ 44'$, making use of the graduation of the circle, lay off on this

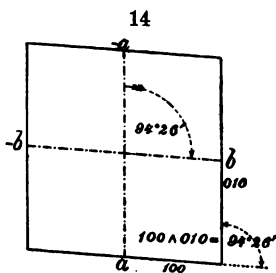


radius the length of the a axis (1.073 in figure 13) using the scale of decimal parts, and then project at right angles to the direction a , $-a$, as indicated by the arrow, thus determining

the length of the foreshortened a axis. For the clinographic projection locate β , $108^\circ 44'$, on the graduation of the ellipse passing through A and C , draw a diameter through the center and fix the length of a by projecting down vertically from a of the orthographic axis above. If one does not wish to make use of the orthographic axes, draw the diameter of the ellipse at the inclination β , and find the length $3a$ by laying off a distance equal to $3a$ on the vertical axis (3.219 in figure 13), using the scale of decimal parts, and then transpose the length thus found to the inclined a axis by drawing a line parallel to β , $-C$, as shown in the figure: One-third of the length thus determined is the desired length of the a axis.

Two processes are involved in plotting the b axis of a triclinic crystal. (1) The vertical plane in which the b and c axes are located is revolved about the c axis so as to conform to the measurement $a \wedge b$, $100 \wedge 010$. Care must be taken to note the direction in which the plane of the b and c axes is turned:

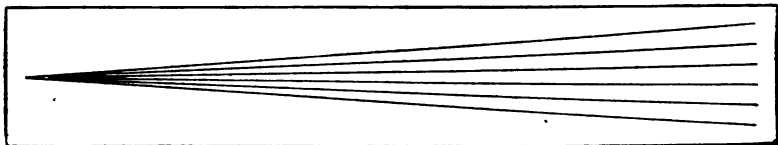
(1) As shown in figure 14, since $100 \wedge 010$ (angle between normals) is $94^\circ 26'$ in rhodonite, the right-hand end of the b axis is first swung forward $4^\circ 26'$ in the plane of the equator. Carrying out the foregoing process in figure 13, a point p is located on the equator, $94^\circ 26'$, measured from $-A$, and likewise b of the orthographic projection above is brought forward to a position $94^\circ 26'$ from $-a$. (2) The horizontal b axis, in its new position, must next be inclined to the vertical axis at the angle α , which in rhodonite is $103^\circ 18'$. For the orthographic projection above, this inclination of the b axis causes some foreshortening, which is determined by laying off two points o and o' , figure 13, $13^\circ 18'$ ($103^\circ 18' - 90^\circ$) on either side of where the b axis intersects the divided circle, and projecting through the points thus formed at right angles to the direction b , $-b$, as indicated by the arrows. To give the b axis of the clinographic projection its proper inclination, the value of α , $103^\circ 18'$, is laid off on two, or preferably three, of the vertical ellipses, as at x , y and z , figure 13, measured from C . Next draw three chords, Ap , $-Ap$ and Bp , on the plane of the equator, and parallel to them, respectively, the chords xx' , yy' and zz' . The common intersection of the three chords determine a point $3b$, on the surface of an imaginary sphere and on a meridian Me passing through p . The point $3b$ is $13^\circ 18'$ below the equator and $103^\circ 18'$, that is α , from C . A line from $3b$ through the center is the projection of the b axis, and a perpendicular from



b of the orthographic projection above will intersect the axis at one-third of its length.

The principle involved in the projection of the clinographic b axis, as given above, is very simple. Imagine a sphere with two points fixed on its equator corresponding to A and p of figure 13, and then a chord Ap through the two points; it then follows that a series of chords parallel to Ap drawn through the 5° , 10° , 15° , etc., graduation points of the meridian through A would all emerge from the imaginary sphere on a meridian Me , figure 13, passing through p , at points 5° , 10° , 15° , etc., from the equator. By drawing two chords, xx' and yy' , as in figure 13, or a third zz' so as to make more certain of the intersection, any desired point on the meridian through p is quickly found. In figure 13 a combination of the prisms m (110) and M ($\bar{1}\bar{1}0$) and the base c (001) has been drawn.

15

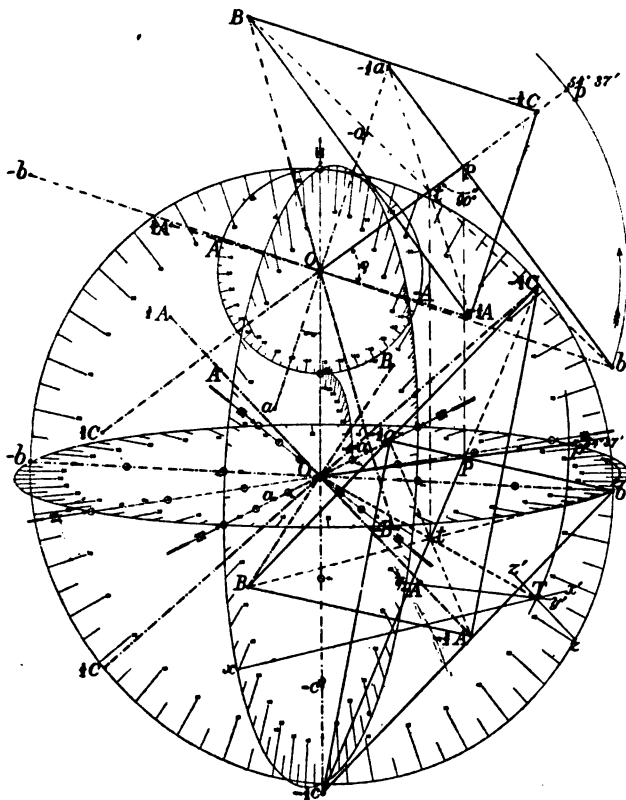


It may be said concerning the protractor that it has been plotted on a large scale to insure accuracy, and that lengths corresponding to one-third those of the axes will generally be found convenient for drawing simple crystal figures. In connection with the protractor it is recommended to use a scale, corresponding to figure 15, printed or drawn on tracing cloth or paper. When the outer lines of such a scale are adjusted between the five degree graduation marks of the ellipses, the intermediate lines will serve to subdivide the space into fifths, or degrees.

Projection of the Axes of twinned Crystals.—The axial protractor furnishes a ready means for plotting the axes of twin crystals, a problem which at times presents considerable difficulty, especially to beginners, hence two examples may be cited explaining the uses of the protractor. In staurolite, twins according to a pyramid are common, and in the example chosen it will be assumed that a face having the symbol $23\bar{2}$ ($-\frac{2}{3}a : b : -\frac{1}{3}c$) is the twinning plane. The data employed in plotting the axes are the axial lengths, $a : b : c = 0.473 : 1 : 0.683$, and the ϕ and ρ angles of the twinning plane; $\phi = 010 \wedge \bar{2}30 = 54^\circ 37'$ and $\rho = 001 \wedge 23\bar{2} = 60^\circ 31'$. To insure accuracy in plotting, the full lengths of the axes of the protractor have been regarded as unity. In figure 16 the axial lengths $-a$ and

$-\frac{2}{3}a : b$; and $-c$, and $-\frac{2}{3}c$ are laid off both on the orthographic and clinographic projections of the axes, and the twinning plane $-\frac{2}{3}a : b : -\frac{2}{3}c$ drawn. The value of ϕ , $54^\circ 37'$, is laid off at p on the equator, measuring in the direction of the arrow from b , and the radius from the center O to p makes an angle of 90° at I' with the line $-\frac{2}{3}a : b$. The twinning axis, a line

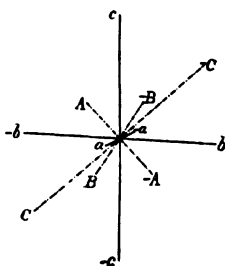
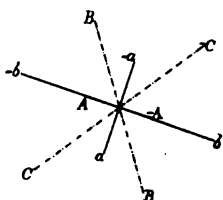
16



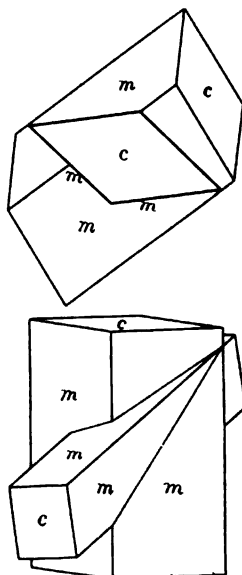
from the centre at right angles to the twinning plane, is now plotted on the clinographic axes by finding a point T , on the meridian through p , $60^\circ 31'$ (the value of ρ) from the south pole of an imaginary sphere. This is done by locating x, y and z on the graduated ellipses at $60^\circ 31'$ from the south pole, and drawing the chords xx', yy' and zz' parallel, respectively, to chords on the plane of the equator through p and the intersections of the a and b axes with the equator. The intersection of the three chords determine the desired point T at the

surface of an imaginary sphere on the meridian through p , and OT is the twinning axis. The point t , where the twinning axis pierces the twinning plane, is determined by the intersection of the twinning axis OT with a line drawn from $-\frac{2}{3}c$ to P . The points p , P and t of the orthographic projection are in vertical alignment with corresponding points on the lower axes, and need no further explanation. Having found t on both the clinographic and orthographic axes, the ends of the axes, $-\frac{2}{3}a$, b and $-\frac{2}{3}c$, are shifted respectively to $-\frac{2}{3}A$, B and $-\frac{2}{3}C$, equidistant from t , as would result from a revolution of

17



18



180° about the twinning axis. Lines from the centers of the two projections through $-\frac{2}{3}A$, B and $-\frac{2}{3}C$ are the axes in twin position. In figure 17 the axes are shown without construction lines, a and b being one-third as long as in figure 16, and in figure 18 two projections of interpenetrating prisms, m , terminated by basal planes, c , are shown.

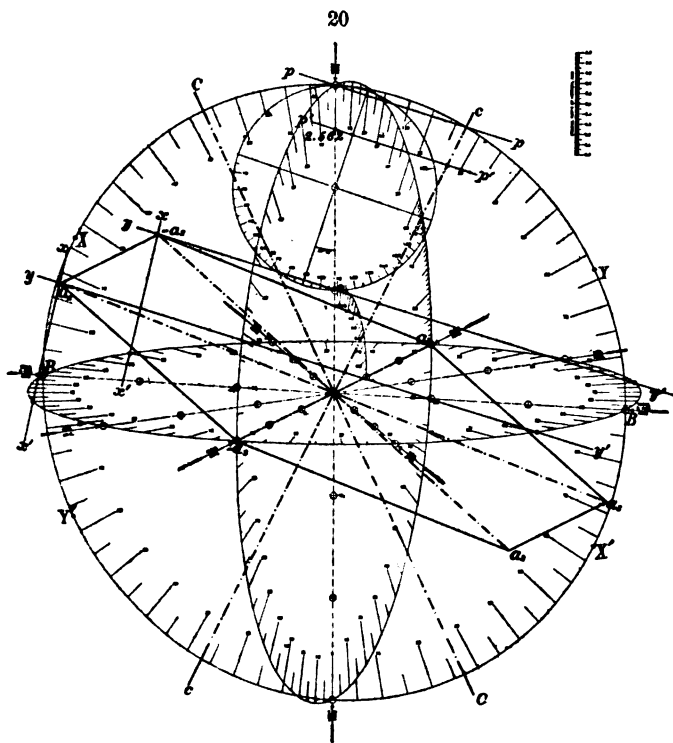
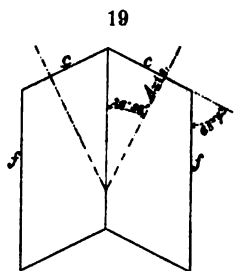
A problem encountered by W. E. Ford and the writer in the study of twin crystals of calcite from Union Springs, N. Y.,* may be cited as a second example for illustrating the uses of the axial protractor in plotting the axes of twin crystals. It was desired to represent a scalenohedron, twinned about the rhombohedron f (0221), so drawn that the

* This Journal (4), x, p. 337, 1900.

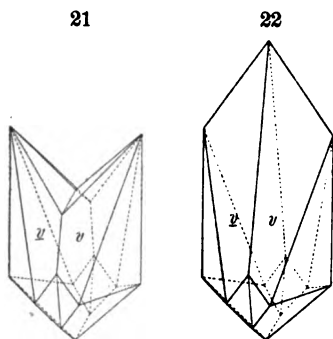
twinning plane should be vertical and have the position corresponding to that of the side pinacoid b (010) of an orthorhombic crystal. The solution depends upon the angle of base on twinning plane, $c \wedge f = 63^\circ 7'$, from which the inclination of the vertical axes, $53^\circ 46'$ from one another, or $26^\circ 53'$ from the twinning plane placed in vertical position, as shown in figure 19, is derived.

As indicated by figure 20, the inclinations of the vertical axes, c and C , $26^\circ 53'$, from the perpendicular, are determined by the graduation of the vertical ellipse through B . Also the intersections of the planes of the horizontal axes with the same ellipse are located at X and X' , and Y and Y' , $26^\circ 53'$ from B and $-B$.

In order to have the twinning plane correspond with the side pinacoid 010 of the orthorhombic system, it is necessary to make one of the horizontal axes $-a, a$, of the hexagonal system correspond with the front and back or a axis of the orthorhombic system. The



other hexagonal axes, therefore, must intersect great circles passing through $-a_1$ and X , and $-a_2$ and Y , at 60° from $-a_1$ and a_1 . To find the desired intersections on the great circle at right angles to one of the twinned axes, c ; through the 60° graduation points on the horizontal ellipse to the left, figure 20, draw the chords xx' parallel to a chord through $-B$ and X ; likewise through the 60° points on the horizontal ellipse to the right draw the chords yy' parallel to a chord through B and X . The intersections of the chords xx' and yy' determine the extremities of the horizontal axes $a_1, -a_1$, and $a_2, -a_2$. To make the drawing somewhat more real, a hexagon at right angles to the twin axis cc has been constructed, by uniting the ends of the horizontal axes. Following a similar process

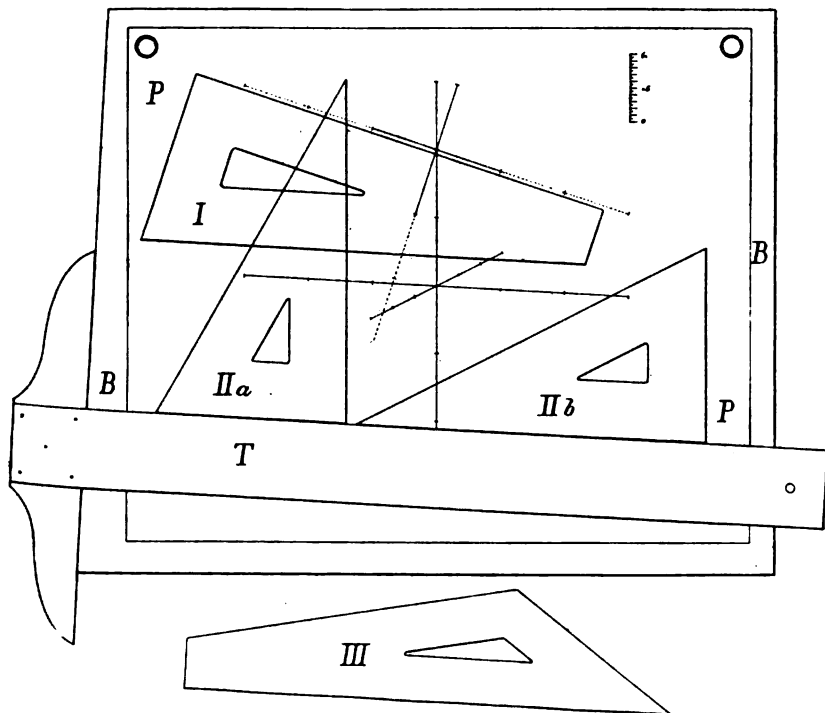


(drawing chords parallel to BY and $-BY$ through the 60° graduation points of the horizontal ellipse) the extremities of the horizontal axes at right angles to the twinned axis C would be found, but it has not seemed best to complicate the figure by carrying out this construction. The length of the vertical axis of calcite is 0.854, and this is plotted on the vertical axis by laying off three times 0.854 (2.562) on the perpendicular, using the scale of decimal parts, and proportioning the length on the twinned c axis by constructing the parallel lines pp and $p'p'$, as indicated in figure 20. Figure 21 represents the scalenohedron $v \{2131\}$ of calcite drawn on the twinned axes, and figure 22 is a development like that observed on the crystals from Union Springs, N. Y., where the re-entrant angle is obliterated by the extension of four of the faces, resulting in a peculiar spear-head shaped development.

Use of T-square and special Triangles.—A T-square may be used to advantage in connection with the engraved axes, figures 9 and 10, the paper PP , figure 23, being adjusted on a drawing board BB so that the blade of the T-square is parallel with the right-to-left or b axis of the clinographic projection. If an ordinary rectangular drawing board is used, the paper may be fastened somewhat askew upon it, and it is not at all necessary to have a board with its right-hand edge cut at a special angle, as shown in figure 23. Special triangles have also proved to be very convenient. One of these is a truncated triangle I , figure 23, so made that when its lower edge is against the blade of the T-square its upper edge is parallel to

the right-to-left of b axis, and its left-hand edge parallel to the front-to-back or a axis of the orthographic projection. A second triangle *II* is shown in two positions in figure 23; *IIa*, when its shorter edge is against the blade of the T-square its right-hand edge is parallel to the vertical axis, and, *IIb*, when one of its longer edges is against the blade of the T-square its upper edge is parallel to the front-to-back or a axis

23



of the clinographic projection. A third triangle *III*, figure 23, is for the hexagonal system, and is so made that when its longer edge is against the blade of the T-square its upper left-hand edge is parallel to the $a_1, -a_1$ axis, and its upper right-hand edge parallel to the $a_2, -a_2$ axis of the clinographic projection; compare figure 10. Thus with T-square and triangles, the axial directions, the essential ones in the construction of a crystal figure, may be had almost instantly, excepting, of course, some of the directions of the monoclinic and triclinic systems.

Uses of the Linear or Quendstedt Projection.—In drawing crystals various methods may be employed for finding the

direction of an edge made by the meeting of any two faces, but the principle depends generally upon locating two points, common to both faces, where they intersect certain axial planes. A line through the points thus found gives the direction of the edge. In general it will be found best to adopt some system for determining the direction of crystal edges, and to adhere to it rather strictly, and the writer has found the method based upon the linear or Quenstedt projection most useful. The projection is too well known to crystallographers to need discussion; as far as it relates to crystal drawing, how-

ever, it will be treated briefly in order to add to the completeness of the present article.

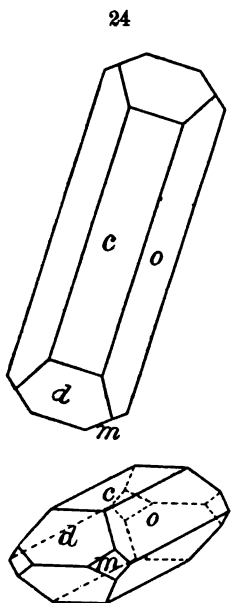
The principle upon which the projection is based is very simple: *Every face of a crystal (shifted if necessary, but without change of direction) is made to intersect the vertical axis at UNITY, and then its intersection with the horizontal plane, or the plane of the a and b axis is indicated by a line.* When it is desired to find the direction of an edge made by the meeting of any two faces, the lines representing the linear projection of the faces are first drawn, and the point where they intersect is noted. Thus a point common to both faces is determined, which is located in the plane of the a and b axes. A second point common to the two faces is unity on the vertical axis, and a line from this point to where the lines of the linear projection intersect gives the desired direction.

A simple illustration, chosen from the orthorhombic system, will serve to show how the linear projection may be employed in drawing. The example is a combination of barite, such as is shown in figure 24. The axial ratio of barite is as follows:

$$a : b : c = 0.8152 : 1 : 1.3136$$

The forms shown in the figure and the symbols are, base c (001), prism m (110), brachydome o (011) and macrodome d (102).

Figure 25 represents the details of construction of the orthographic and clinographic projections shown in figure 24. On the orthographic axes the axial lengths a and b are located, the vertical axis c being foreshortened to a point at the center. On the clinographic axes, centered at O , the ends of the axes a and b are located by dropping perpendiculars from corre-



the line representing its linear projection. It is well to note that the intersections x, y and z and x', y' and z' are in vertical alignment with one another.

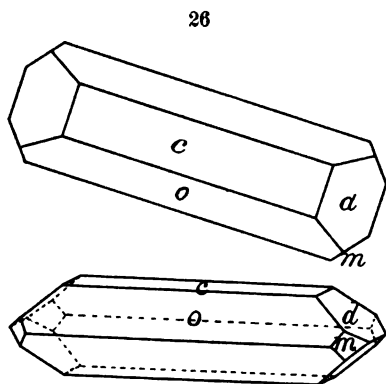
Concerning the drawing of figure 25, it is a simple matter to proportion the general outline of the barite crystal in orthographic projection. The direction of the edge between $d, 102$, and $o, 011$, is determined by finding the point x , where the lines of the linear projection of d and o intersect, and drawing the edge parallel to the direction from x to the center c . The intersection of the prism $m, 110$, with d and o is a straight line, parallel to the direction a to b or y to z . To construct the clinographic figure, at some convenient point beneath the axes the horizontal middle edges of the crystal may be drawn parallel to the a and b axes, their lengths and intersections being determined by carrying down perpendiculars from the orthographic projection above. The intersection between $d, 102$, and $o, 011$, is determined by finding the point x' of the linear projection and drawing the edge parallel to the direction from x' to 1 (*unity*) on the vertical axis, while the corresponding direction below is parallel to the direction x' to -1 . The size of the prism $m, 110$, and its intersections with d and o may all be determined by carrying down perpendiculars from the orthographic projection above, but it is well to control the directions by means of the linear projection: The edges between $m, 110$, and $d, 102$; and $m, 110$, and $o, 011$, are parallel respectively to the directions y' to 1 and z' to 1. Having completed a figure, a copy free from construction lines may be had by placing the drawing over a clean sheet of paper and puncturing the intersections of all edges with a needle-point: An accurate tracing may then be made on the lower paper.

Should it happen that the linear projection made on the plane of the a and b axes gives intersections far removed from the center of the figure, a linear projection may be made on the clinographic axes either on the plane of the a and c or b and c axes, supposing that the faces pass, respectively, through *unity* on the b or the a axes.

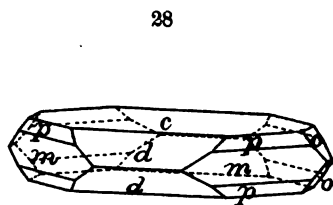
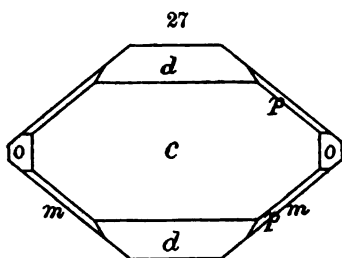
Importance of an Orthographic in connection with a Clinographic Projection.—There is no question in the writer's mind that many students, on commencing the study of crystallography, fail to derive the benefit they should from the figures given in text-books. Generally clinographic projections are given almost exclusively, with perhaps occasional basal or orthographic projections, and beginners find it hard to reconcile many of the figures with the appearance of the models and crystals which they are intended to represent. For example, given only the clinographic projection of barite, figure 24, it takes considerable training and knowledge of the projection

employed to gain from the figure a correct idea of the proportions of the crystal which it actually represents. This may be shown by comparing figures 24 and 26, which represent the same crystal, drawn one with the a , the other with the b axis to the front. It is seen from figure 26 that the crystal is far longer in the direction of the a axis than one would imagine from inspection of only the clinographic projection of figure 24. The front or a axis is much foreshortened in clinographic projection, consequently by the use of only this one kind of projection there is a two-fold tendency to err; on the one hand, in drawing, one is inclined to represent those edges running parallel to the a axis by lines which are considerably too long, while, on the other hand, in studying figures there is a tendency to regard them as representing crystals which are too much compressed in the direction of the a axis. By using

orthographic in connection with clinographic projections these tendencies are overcome. Having in mind the proportions of a certain crystal, or having at hand a model, it is easy to construct an orthographic projection in which the a and b axes are represented with their true proportions; then the construction of a clinographic projection of correct proportions follows as a comparatively simple matter. Without an orthographic projection it would have been a difficult task to have constructed the clinographic projection of figure 26 with the proportions of the a and b axes the same as in figure 24, while with the orthographic projection orientated as in figure 26 it was an easy matter. Then again, given a model for study, say of barite corresponding to figure 24, a student holding the model properly orientated, over or near to the orthographic projection, and looking down on it from above, sees at once the relations between the model and the figure: Prismatic angles have their true value in the drawing, and the directions and relative lengths of all of the edges appear to be the same as on the model. From an orthographic projection alone, however, one can gain no conception of the length of a crystal in the direction of the vertical axis, nor of the steepness of its terminal faces: A combination of two projections is needed, and from two figures a proper conception of the development

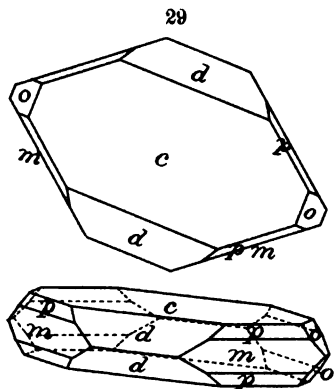


of a crystal may be had. Without question, in many and perhaps the majority of cases, figures in orthographic projection would be far more helpful to beginners, especially if studied in connection with models, than the ones so commonly used which are in clinographic projection alone. An architect in working out the details for any structure would never think of



submitting to a builder a plan alone, or only an elevation: Two kinds of figures are considered as necessary, plans and elevations, and in like manner students of crystallography need figures drawn in two projections in order to derive the full benefit from them.

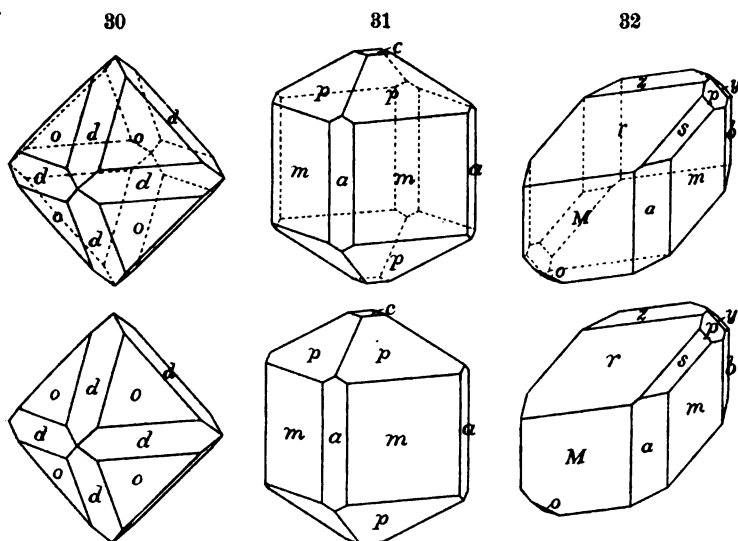
Position of Figures.—If orthographic and clinographic projections are to be used together there is some choice as to the position in which the figures should be placed. Taking barite as an example: If an orthographic projection alone were employed there is no question but that the drawing should be orientated as in figure 27, with the direction of the *a* and *b* axes parallel respectively to the vertical and horizontal edges of the page. Provided two projections are used, however, if the clinographic, figure 28, is placed to one side of the orthographic, or directly below it, the apparent connection between



the two figures is not at all evident: To place them thus is in violation of the principles of mechanical drawing and projection, and it is hard to realize that figures 27 and 28 are representations of the same crystal. Placed as in figure 29, however, it takes but little study to understand how the two projections are related. It is true that it may at first seem strange to see the orthographic projections skewed around at

an angle of $18^{\circ} 26'$, but this is a condition to which one would soon become accustomed. If orthographic and clinographic projections are to be used together for purposes of illustration, it is believed that the orthographic projections should be left in the position in which they were drawn, and printed as in figure 29, although this is a matter which need not be insisted upon.

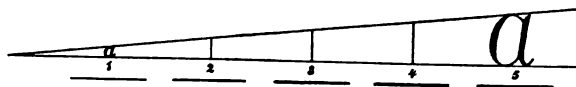
Stereoscopic Effect.—It has frequently been observed that the figures in text-books do not convey to many students the impression of solidity, and this is a defect which probably has



been generally recognized. Some have sought to overcome the difficulty by making use of two projections drawn at slightly different angles, as a crystal would appear if seen from the positions of the right and left eyes, and then viewing the two pictures with a stereoscope. The effects produced are most satisfactory, but for purposes of text-book illustration and for class-room work the method is scarcely practical. If a clinographic projection is well drawn, with the front edges represented by full lines and the back edges by somewhat lighter, dashed lines, a very satisfactory and at times quite remarkable stereoscopic effect may be had by viewing the figure through a tube. The practice is one commonly employed by artists in studying effects. The tube may be a roll of light or dark paper, either cylindrical or conical, quite variable in size (6^{cm} long by 1^{cm} diameter gives good results), while the most convenient thing to use is one's hand, doubled up so as

to form a sort of tube. Stereoscopic effects are more pronounced with some figures than with others, but they would seem to depend to a large extent upon the proper proportioning of the heavier front and lighter (dashed) back lines. It is believed that the reason for the stereoscopic effect is not far to seek;—it seems to be wholly an optical illusion.—By looking through a tube the attention is concentrated on a single figure, and the heavy lines produce the effect of being near, the fainter, dashed lines of being farther away; hence the conception of solidity. In order that the stereoscopic effect may be observed by the reader, illustrations of three crystals are given for comparison, drawn with and without dashed back lines; Figure 30 is a combination of dodecahedron, *d*, and octahedron, *o*, magnetite; figure 31 is a combination of prisms of the first and second order, *m* and *a*, terminated by pyramid and base, vesuvianite; and figure 32 is a combination of triclinic forms observed on axinite. Except for stereoscopic

33

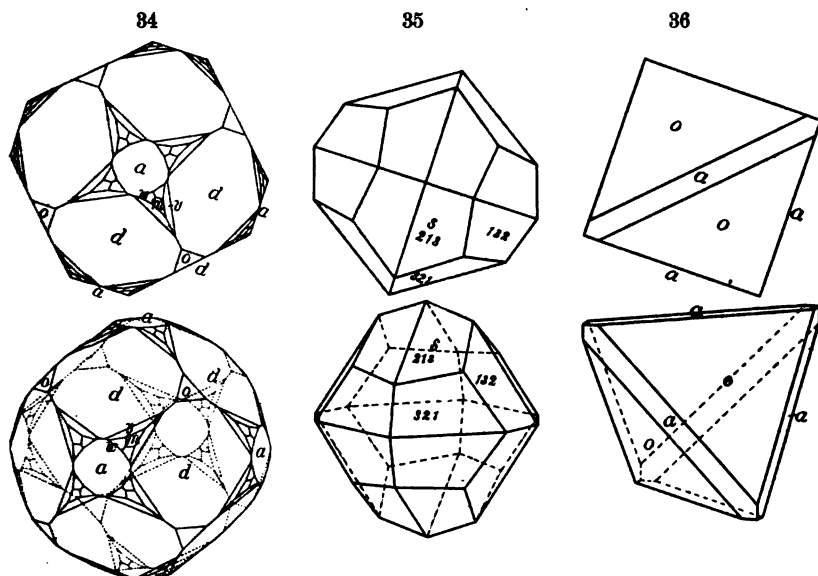


effect it may be questioned whether dashed back lines are not at times as much of a hindrance as a help in the understanding of crystal figures, because of the complexities which they introduce. As a rule they certainly add to the effectiveness of a figure, but not always; for example, in figure 18, page 50, it seemed far better to do without them.

Size of Original Drawings; Lettering.—Generally speaking, the size of an original drawing should depend to a large extent upon the complexity of the figure. It may be recommended to draw simple figures three or four times as large as needed for illustration, while with a complex subject like figure 34 it is almost impossible to make a drawing with accuracy except on a scale seven or eight times the size of the illustration. Figure 34 represents a crystal with 240 edges; hence it is evident that it is necessary to make the original drawing on a large scale in order to preserve with accuracy the directions of the many short lines.

If figures are to be reduced by the photo-engraving process, they must be drawn in ink and lettered to suit the reduction. Figure 33 gives the approximate width of line and size of letter to be used with various degrees of reduction indicated by the numbers. Almost any one can succeed fairly well in forming letters who will take pains and make use of good models.

Uniformity of Lettering.—A gain has been made in recent years in adopting some uniformity in lettering, as must be appreciated by all who are accustomed to use Dana's System of Mineralogy. The scheme there adopted is in general to indicate the three pinacoids, 100, 010 and 001, by *a*, *b* and *c*, respectively, and the prism 110 by *m*. In the hexagonal and rhombohedral systems the prisms of the first and second orders are designated by *m* and *a*, respectively, in conformity with the usages of the tetragonal system, and the unit rhombohedron is designated by *r*. In the isometric system the cube, octahedron and dodecahedron are lettered *a*, *o* and *d*, respectively.



tively. The writer recommends going still one step further and designating the form 111 (isometric system excepted) always by *p*, but to carry the scheme beyond this point would be cumbersome and scarcely practicable. In using Dana's Mineralogy, or reading any article in which the scheme as outlined above is followed, a glance at the figures will generally serve to indicate the character of the forms, for however complicated a crystal may be, it is almost certain that some of the above mentioned forms will be present. It is hoped that the scheme will be more generally adopted than it is at present.

Examples.—In conclusion some figures will be given illustrating numerous advantages derived from drawing crystals in both orthographic and clinographic projection.

For the normal group of the isometric system, the forms observed on a specimen of magnetite in the Brush Collection, from Achmatowsk, Ural Mts., figure 34, has been chosen. The figure was drawn by Mr. R. G. Van Name when a student in the writer's laboratory. The combination is unusually complex, trapezohedron m (311) and two hexoctahedrons, v (531) and w (21.7.5), besides the simple forms a , o and d . A similar combination, but with somewhat different development of the forms, is described by Kokscharow.* In the construction

of the complex clinographic figure, the orthographic projection proved to be a great help.

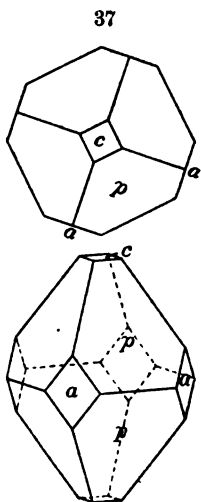
Both in drawing and in the study of forms of lower symmetry, orthographic projections are very helpful. Figure 35 represents the diploid s , (321), and figure 36 a combination of cube a and tetrahedron o . It is the writer's experience that the average student has great difficulty in gaining an idea of tetrahedral forms from figures in clinographic projection, yet a combination of cube and tetrahedron if orientated and looked at from above, in the direction of the vertical axis, will appear exactly like the orthographic projection of figure 36, hence the value of the figure.

Figure 37 represents a simple combination of the tetragonal system observed

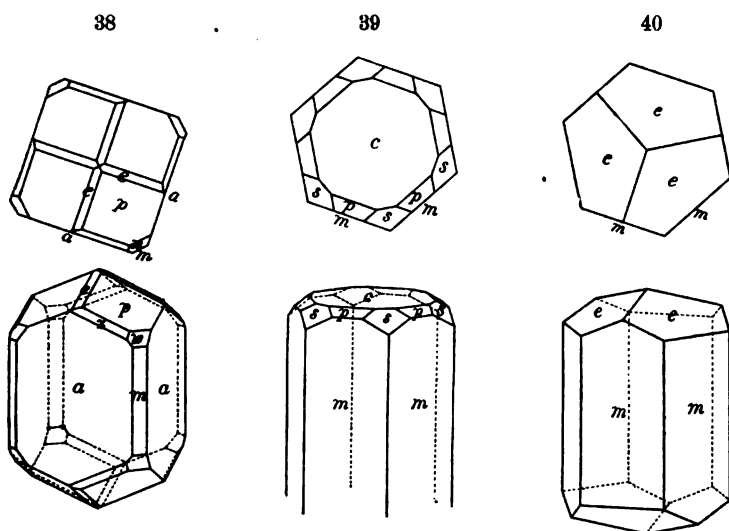
on apophyllite; prism of the second order a , base c , and pyramid of the first order p (111). The clinographic projection alone gives a very satisfactory idea of the general proportion of the crystal, but the imagination must be drawn on to grasp the idea that the pyramid is tetragonal, a property which is brought out by a glance at the accompanying orthographic projection.

Figure 38 is a combination belonging to the tri-pyramidal group of the tetragonal system, observed on scapolite from Templeton, Canada. The forms are two prisms a and m , terminated by pyramids of the first order p (111) and w (331), of the second order e (101) and of the third order z (311). From the standpoint of a student desiring to understand the relations of the three kinds of pyramids of this group, it is believed that the orthographic is the most helpful of the two projections, although the clinographic is needed to give an idea of the general proportions of the crystal.

* Mineralogie Russlands, vol. iii, p. 47.



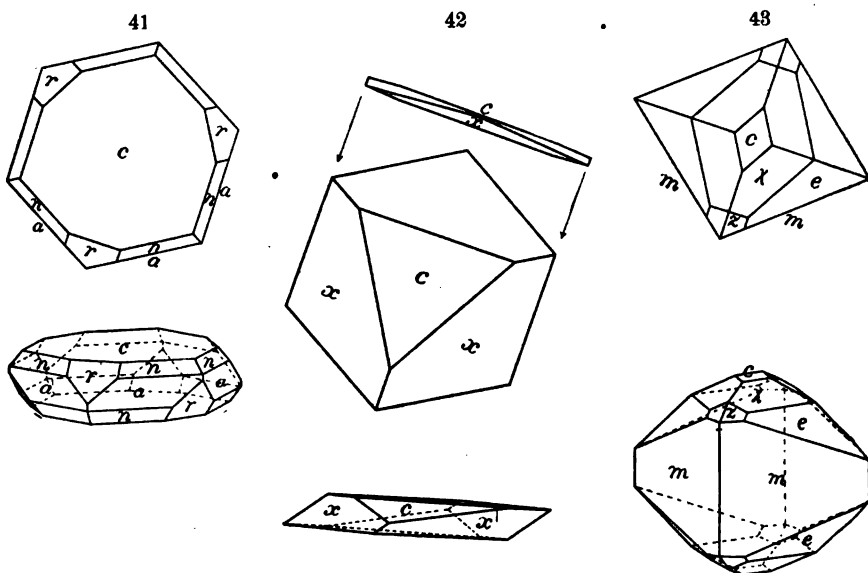
In the combination observed on beryl, c (0001), m (10 $\bar{1}$ 0), p (10 $\bar{1}$ 1) and s (11 $\bar{2}$ 1), figure 39, it takes considerable imagination to grasp the idea of the hexagonal shape and distribution of the pyramidal forms from the clinographic projection alone, relations which are at once brought out with distinctness by means of the accompanying orthographic projection. In the rhombohedral group of the hexagonal system clinographic projections alone are at times quite inadequate for representing the shapes of crystals. For example, given the clinographic



projection alone, figure 40, it may well be imagined that beginners have difficulty in understanding the simple type of calcite crystal represented, prism m , terminated by the flat negative rhombohedron e (01 $\bar{1}$ 2), but with the accompanying orthographic projection, the hexagonal nature of the prism and the distribution of the terminal faces about the vertical axis with trigonal symmetry is evident. The two projections, figure 41, supplement one another in giving an idea of the proportions and arrangement of the faces observed on a crystal of corundum from Cowee Creek, Macon Co., N. C. Figure 42 represents a crystal of hematite from Fowler, N. Y., showing the combination of the base c and a very flat rhombohedron x (0 \cdot 1 \cdot 1 \cdot 12). In this case the clinographic projection alone is quite inadequate, for although the figure is a correct representation in so far as the projection is concerned, it is next to impossible to gain from it a correct conception of the shape and proportions of the crystal which it is intended to represent. The

orthographic projection above, accompanied by the statement that the rhombohedron is very flat, $c \wedge x = 7^\circ 29'$, enables one to gain an idea of the shape of the crystal, while a second orthographic projection which represents the crystal when viewed edgewise, that is so that the base is foreshortened to a line, has been introduced to indicate how very thin the crystal really is.

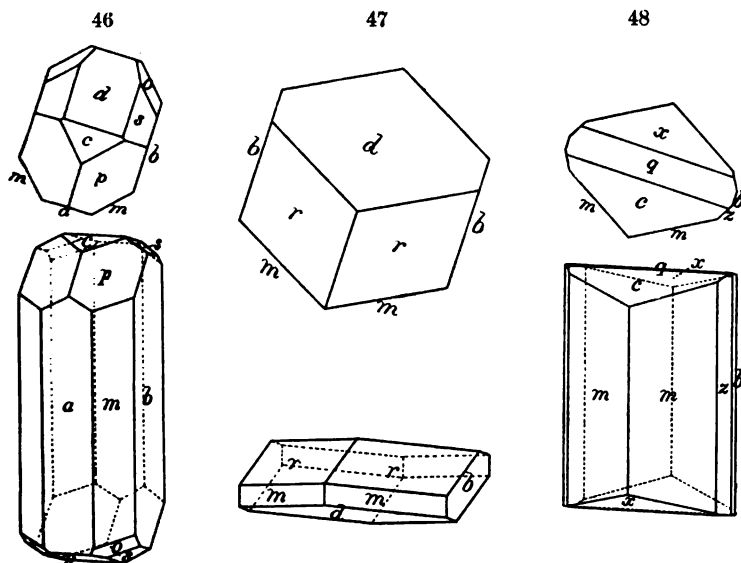
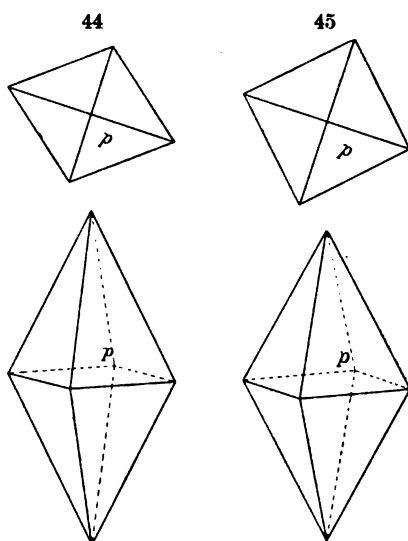
For the orthorhombic system, illustrations have already been given of the use of orthographic projections both in drawing



and in the understanding of the forms of barite crystals. Figure 43 is offered as an additional illustration: It represents a combination observed on brookite from Magnet Cove, Arkansas. From the clinographic projection alone it is very difficult to gain an appreciation of the proportions of the crystal; while the orthographic projection is excellent for showing the distribution of the terminal faces and zonal relations. Figures 44 and 45 represent pyramids of sulphur and octahedrite, respectively. Considering the clinographic projections alone, it takes careful inspection to discover any difference between the two figures, while the accompanying orthographic projections indicate at a glance that the pyramid is orthorhombic in the one case and tetragonal in the other.

In the monoclinic system, the clinographic projections alone, figures 46, 47 and 48, need to be supplemented by the accompanying orthographic projections in order that the real shapes

of the crystals may be fully appreciated. Taking another example; it has always seemed to the writer that the clinographic projection of epidote, figure 49, was poorly adapted for showing the form of so simple a crystal. It represents a combination lengthened in the direction of the *b* axis and terminated by two faces *n* ($\bar{1}11$), one of which, however, in the position adopted, happens to be foreshortened to a line. The accompanying orthographic projection, especially if studied in connection with a model, helps to give an understanding of



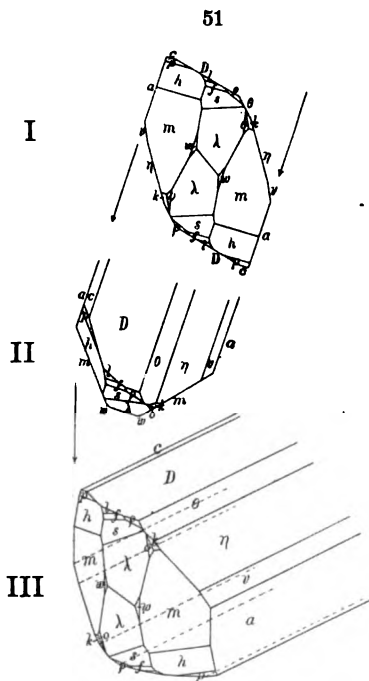
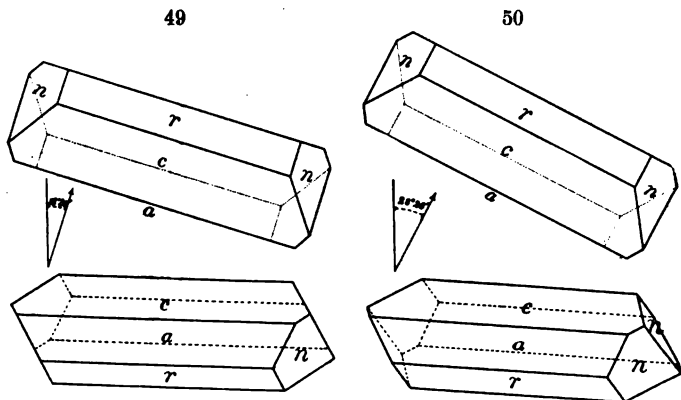
Pyroxene.

Tremolite.

Adular.

the shape. A clinographic projection better adapted for giving an idea of the development of the crystal is shown in figure 50.

In this case the revolution about the vertical axis is $28^{\circ} 26'$ instead of $18^{\circ} 26'$, as in the previous illustrations, and both terminal faces are thus shown in the lower figure. By means

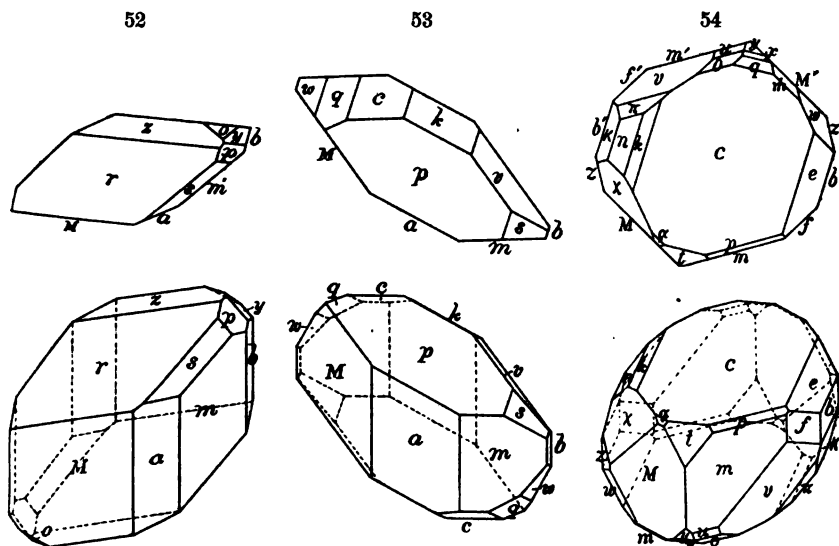


of the axial protractor, page 44, it is an easy matter to plot the axes in the position chosen.

Owing to foreshortening, without the use of an orthographic projection it often becomes a very difficult matter to construct a figure in clinographic projection in which the relative proportions of the several faces of a crystal are preserved with accuracy. A case illustrating this, encountered in the study of some very beautiful and complex crystals of azurite from Broken Hill mines, New South Wales, figure 51, may be cited. The drawings were made by Mr. R. G. Van Name when a student in the writer's laboratory. The crystals, lengthened like epidote in the direc-

tion of the b axis, showed only one termination, and the clinographic projection III represents the crystal turned

so that the *b* axis runs from front to back. The list of forms is not given here because, if needed, it may be found in an earlier publication.* Endeavoring to preserve the true proportions of the faces, it proved to be a difficult matter to construct the orthographic projection II, as seen in the direction of the vertical axis. An end view of the crystal, an orthographic projection as seen in the direction of the *b* axis I, was therefore first drawn, a comparatively easy task, and tilting it at an angle of $18^{\circ} 26'$, as shown in the figure, the



orthographic projection II was readily made by projecting as indicated by the arrows, and, finally, the clinographic projection III, in exactly the desired proportions was made. In studying the forms of a complex crystal, such as represented by figure 51, the orthographic projection I (end view) is doubtless more satisfactory than either of the other projections.

For the triclinic system three illustrations are offered. The clinographic projection of axinite, figure 52, is very satisfactory, but its proportions are made more real by the accompanying orthographic projection. In the examples chalcantinite and anorthite, figures 53 and 54, the clinographic projections taken alone are inadequate because of the foreshortening of several of the prominent faces, but supplemented by the accompanying orthographic projections the combinations are readily

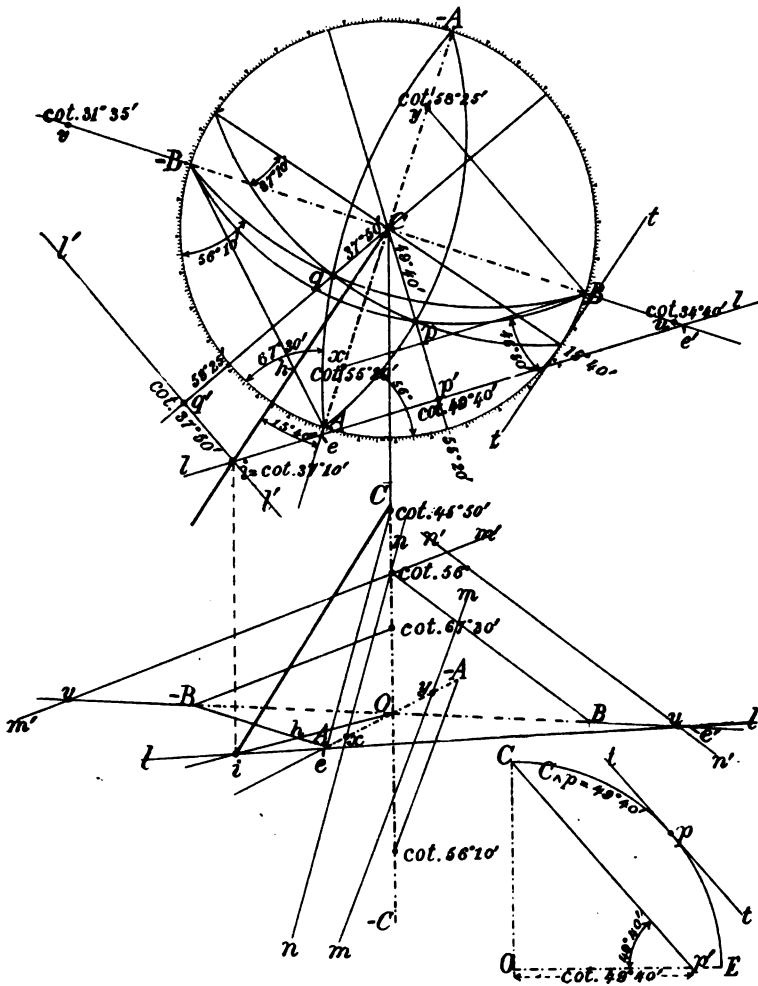
* This Journal (4), xiv, p. 278, 1902.

understood. The complicated figure of anorthite was drawn by Mr. J. C. Blake of the writer's laboratory.

Conclusion.—It is not the object of the present communication to make the subject of crystal drawing easy. The drawing of a complex combination requires patience, skill, and above all a knowledge of the principles of crystallography and mechanical drawing. For some persons the subject is a very easy one, while others acquire it only with difficulty, differences depending upon personal peculiarities. That correct ideas of the shapes of crystals should be obtained from figures is evident, and those who are familiar with crystallography, especially if they are not called upon to teach it, have difficulty perhaps in appreciating how hard it is for some persons to see the relations between a figure and the crystal which it represents. The clinographic projection is undoubtedly as good a one as can be found for representing the shapes of crystals, but, as has been pointed out, in many cases a figure thus drawn should be supplemented by one in orthographic projection. Orthographic projections are so simple that they may be made easily, even sketched free hand with some approximation to accuracy, and it is especially desired to emphasize their value as a help both in drawing and in the understanding of crystal figures. In the majority of cases two figures, one in orthographic and the other in clinographic projection, may be made in less time than a single figure in clinographic projection. The engraved axes, axial protractor and special triangles, having been in use for more than four years in the writer's laboratory, have proved their efficiency: by means of them increased accuracy in drawing is attained, time is saved, and, what is of no little importance, strain on the eyes is materially lessened.

Drawing from the Stereographic Projection.—A stereographic projection of the faces of a crystal, or, for that matter, of any geometrical figure with plane surfaces, furnishes all the data needed for constructing figures in both orthographic and clinographic projections. In the methods to be described use will be made of three lines or axes; one a vertical, corresponding to the north and south axis of a sphere, the others at right angles to one another in the plane of the equator. In the upper part of figure 55 the two diameters of the graduated circle, $A, -A$ and $B, -B$, represent the front-to-back and right-to-left axes in the plane of the equator, the vertical axis, $C, -C$, being foreshortened to a dot at the center. The axes have been turned as it were through an angle of $18^{\circ} 26'$ in order to make $A, -A$ and $B, -B$ correspond with the directions of the axes for orthographic projection of figure 1. It is supposed that in figure 55 p is the pole of some crystal face: From the graduated circle it is seen that p is on the meridian

55



* For a description of the stereographic scales and protractors mentioned in this and the succeeding paragraphs, the reader is referred to the earlier publications of the writer: "The Stereographic Projection and its Possibilities from a Graphical Standpoint," this Journal (4), xi, pp. 1-24 and 115-144, 1900; and "On the Solution of Problems in Crystallography by Means of Graphical Methods, based upon Spherical and Plane Trigonometry," Ibid., xiv, pp. 249-284, 1902.

surface, a plane surface tangent to the sphere at p would be parallel to the crystal face under consideration, and, if extended, it would intersect the plane of the equator on a line at right angles to a radius drawn through the intersection of the meridian of p and the equator. In the lower right-hand corner of figure 55 the arc CE is supposed to represent a portion of the meridian through p ; C is the north pole of the sphere, OE the trace of the plane of the equator and tt the trace of the tangent at p : If now the tangent plane is shifted, without change of direction, until it intersects C (*unity* on the vertical axis) it will intersect the radius OE in the plane of the equator at p' . The linear projection of p is therefore found by determining the point p' , where a plane parallel to the tangent at p and intersecting the vertical axis at C cuts the radius drawn through p , and then drawing the line of the linear projection, ll , at right angles to the radius. Knowing the distance C to p in degrees, the point p' where the line ll crosses the radius through p may be readily found in three ways: (1) Graphically, as shown in the lower right-hand corner of figure 55; (2) From the same figure it is evident that Op' is the cotangent of the angle $Cp'O$ or of the arc $C \wedge p$; the value of the cotangent may be found from a table of natural tangents and cotangents and laid off on the radius through p by means of a scale of decimal parts; (3) A cotangent scale may be prepared, based on the radius of the circle as *unity*, and the distance Cp' laid off directly from the graduation. The latter method is probably the best, and a scale for laying off cotangents may be easily had by a simple modification of the stereographic scale, No. 3, of the engraved sheets described by the writer.* The basis of the stereographic scale is that the distance from the center to any pole, for example, C to p , figure 55, is equal to the tangent of half the arc $C \wedge p$; hence in order to prepare a scale for laying off tangents and cotangents it is only necessary to take a stereographic scale and renumber it, making 20° of the one equal to 10° of the other. On applying such a scale to a radius of the graduated circle for laying off cotangents, 90° is located at the center (the cotangent of $90^\circ = 0$), and 0° falls at infinity. The reason for using a cotangent instead of a tangent scale (when the numbering would run in the opposite direction) is that cotangents are better adapted to the ϕ and ρ angles of the two-circle goniometer. Having a second pole q , $37^\circ 50'$ from C , figure 55, its linear projection is the line $l'l'$. The two lines of the linear projection ll and $l'l'$ intersect at i , and the direction of the edge made by the intersection of p and q will be parallel to the line joining C and i .

*Loc. cit.

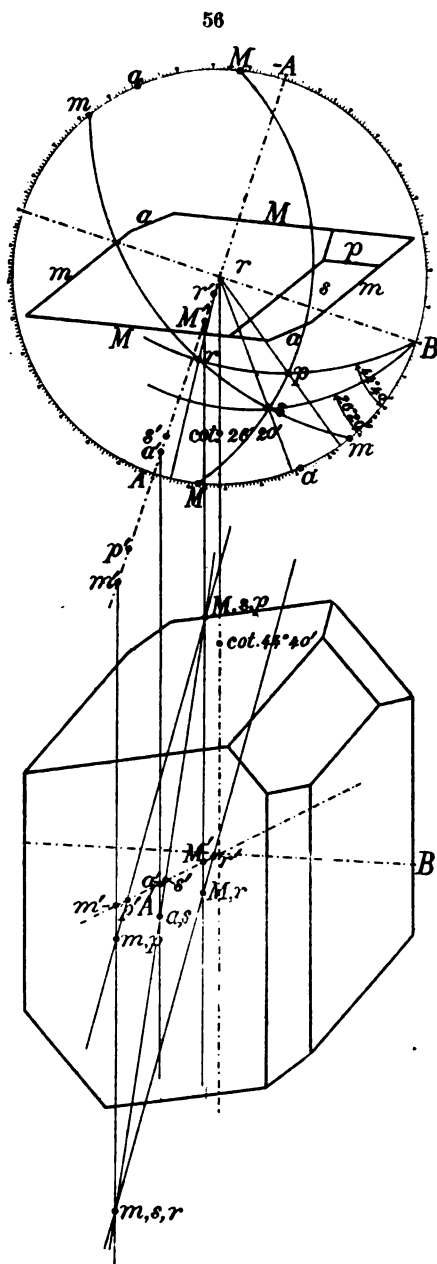
Still another way in which the direction Ci may be found is as follows: Among the stereographic protractors described by the writer there was one consisting only of great circles printed on celluloid (Protractor No. *IV*). Having p and q located, the protractor is centered over the projection and turned until p and q fall on the same great circle, and then the points where the great circle intersects the divided circle ($15^{\circ} 40'$ from B in figure 55), are noted, although it is not necessary to draw the great circle as in the figure. It follows from this that p and q are in a zone with a vertical plane, the pole of which is located at $15^{\circ} 40'$ from B : The intersection of such a vertical plane with the plane of the equator would be parallel to the line tt , tangent at $15^{\circ} 40'$, or, simpler, it would be parallel to a line from the center C to a point on the graduated circle $15^{\circ} 40'$ from A , which is identical with the direction Ci found by means of the linear projections of p and q . The method of the great circle protractor has one decided advantage; it is not necessary to make any construction lines; the position of the protractor alone determines the desired direction. The line Ci in orthographic projection may be regarded as representing two things: (1) a radius drawn on the plane of the equator, and (2) the projection of the edge between p and q , passing through unity on the C axis and intersecting the plane of the equator at i : the point i is an important one to determine, and may be found by noticing the angle which the great circle through p and q makes with the diameter, $37^{\circ} 10'$ in figure 55, and locating i by means of the cotangent scale.

In order to find the intersection between two planes in clinographic projection, p and q , figure 55, proceed as follows: Through C and a point $18^{\circ} 26'$ to the right of A on the graduated circle, draw a line, and continue it for some distance below the circle, to represent the vertical axis. As shown in figure 23, page 53, the vertical axis is next made parallel with the edge of the special triangle IIa resting on a T-square, then, at some convenient distance O , the lines B , $-B$ and A , $-A$ are drawn with the aid of a T-square and the special triangle IIb to represent the right-to-left and front-to-back axes. Unit lengths on the axes are determined by projecting down from A , $-A$ and B , $-B$ of the orthographic axes above, and a distance equal to the radius of the graduated circle is laid off above and below O , at C , and $-C$, to represent unity on the vertical axis. If the special triangle referred to is not at hand, the clinographic A , $-A$ and B , $-B$ axes may be constructed readily from the details given on pages 40 and 41, in connection with figures 1 to 4. If on the orthographic axes above the linear projection of p , that is the line U , has been drawn, its intersec-

tions with the A and B axis, e and e' , are noted and points corresponding to this are projected down on the clinographic axes beneath. The line ll , through e and e' on the lower axes, is the linear projection of p . The point i , the intersection of ll and $l'l'$ of the orthographic projection above, may now be transferred to the line ll of the lower axes by projecting down parallel to the vertical axis: the intersection between p and q is parallel to the line from C to i . If the point i on the upper axes has been determined by means of the cotangent scale, without the use of the linear projection, the corresponding point i on the lower axes may be found as follows: On both the upper and lower axes draw lines from A to $-B$, and on the upper axes note the point h where the lines A to $-B$ and Ci cross; on the lower axes find the corresponding point h on the line A to $-B$ by projecting down from h above, draw a line from O through h and find i by projecting down from i above.

In following out the methods just described, two conditions may be encountered which give rise to difficulties; (1) the pole of a certain crystal face may be located within a few degrees of the center of the stereographic projection, in which case the line representing its linear projection would be so far removed from the center that it is difficult to construct it, and (2), two lines of a linear projection may happen to be so nearly parallel that their intersection falls too far from the center of the figure for convenience of drawing. Such difficulties may be overcome easily by making the linear projection either on the plane of the A and C axes, supposing the faces to pass through *unity* on B ; or on the plane of the B and C axes, supposing that the faces intersect *unity* on A . To illustrate how a linear projection may be made on the plane of the A and C axes:—The pole p , figure 55, is on the meridian $55^{\circ} 20'$ from B , and a crystal face corresponding to p would intersect the plane of the equator at right angles to a radius drawn to a point on the equator $55^{\circ} 20'$ from B ; such a plane if shifted so as to intersect B at *unity* would intersect the A axis at the point marked x , cot. $55^{\circ} 20'$ (best laid off with the cotangent scale), which is projected down upon the A axis beneath. The great circle stereographic protractor is next centered over the projection, and it is found that the great circle passing through B and p makes an angle of $45^{\circ} 50'$ with the equator at B ; hence it follows that all the possible faces in the zone Bp , if made to intersect A at *unity*, would intersect the vertical axis at a distance equal to the cotangent of $45^{\circ} 50'$ measured from the center. By means of the cotangent scale the point cot. $45^{\circ} 50'$ is laid off from O on the vertical axis and the linear projection of p is the line nn , drawn through x , previ-

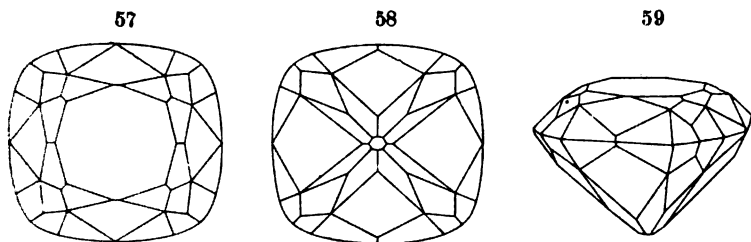
ously determined, and parallel to the direction from A to the point $\cot. 45^\circ 50'$ on the vertical axis. In the case of q , figure 55, being on the meridian $58^\circ 25'$ from $-B$, a little explanation is necessary: A crystal face corresponding to q , when shifted so as to intersect $+B$, will intersect the negative ends of the A and C axes; the former at the point marked y , $\cot. 58^\circ 25'$, which is projected down on the A axis beneath. The great circle through $-B$ and q makes an angle of $56^\circ 10'$ with the equator, and the point $\cot. 56^\circ 10'$ is laid off in this case on the negative end of the C axis. The linear projection of q is then the line mm , drawn through y and parallel to the direction from $-A$ to the point $\cot. 56^\circ 10'$ on the vertical axis. The lines nn and mm intersect at some distance from the center of the axes, but if continued it is found that a line from $+B$ to their point of intersection is parallel to the direction Ci . If it is desired to make the linear projection



on the plane of the *B* and *C* axes, the data are as indicated in figure 55: The meridians of *p* and *q*, $34^{\circ} 40'$ and $31^{\circ} 35'$, measured from *A* (their cotangents plotted at *u* and *v*), and the angles which the great circles through *A* and *p* and *A* and *q* make with the equator, 56° and $67^{\circ} 30'$, respectively. The linear projection of *p* is the line *n'n'*, drawn through *u* parallel to the line from *B* to the point cot. 56° on the vertical axis; and the linear projection of *q* is the line *m'm'*, drawn through *v*, parallel to the line from *B* to the point cot. $67^{\circ} 30'$ on the vertical axis. A line drawn from *A* to the point of intersection of *n'n'* and *m'm'* is the desired direction, and is parallel to the line *Ci*.

As an illustration of the application of the methods just described, the details of a drawing of a crystal of axinite may be cited. The forms present are shown in the stereographic projection, figure 56: *m* (110), *a* (100), *M* ($\bar{1}\bar{1}0$), *p* (111), *r* ($\bar{1}\bar{1}1$) and *s* (201). It was found that on making the linear projection on the plane of the *A* and *B* axes, several of the lines were so nearly parallel that it was difficult to determine some of the intersections. It was decided, therefore, to make the linear projection on the plane of the *A* and *C* axes as shown in the figure, the data needed being derived from the stereographic projection, as follows: Meridians of the poles, measured from *B*: *m* $32^{\circ} 47'$; *p* $35^{\circ} 50'$; *a* $48^{\circ} 21'$; *s* 51° ; *M* $77^{\circ} 16'$ and *r* 85° ; also the angles made by the great circles *Bpr* and *Bs* with the equator, $44^{\circ} 40'$ and $26^{\circ} 20'$, respectively. The cotangents of the meridians of the several poles are laid off on the orthographic *A* axis at *m'*, *p'*, *a'*, *s'*, *M'* and *r'*, and projected down on the clinographic *A* axis. The linear projections of the faces of the prismatic zone are vertical lines through *m'*, *a'* and *M'*; those of *p* and *r* are lines through *p'* and *r'*, parallel to the direction from *A* to the point on the vertical axis marked cot. $44^{\circ} 40'$; and that of *s* the line through *s'*, parallel to the direction from *A* to the point on the vertical axis marked cot. $26^{\circ} 20'$. All of the intersections of the figure in clinographic projection are parallel to lines drawn from *B* to points of intersection on the linear projection, indicated by the lettering. Thus the orthographic and clinographic figures of axinite were made wholly without reference to the lengths and inclinations of the triclinic axes and the symbols of the faces.

Figure 57 represents a cut stone (brilliant) as seen from above, and figure 58 as seen from below in orthographic projection, while figure 59 is a clinographic projection of the same. These drawings were made from two-circle goniometer measurements plotted in the stereographic projection. The object measured was a glass model of the Regent or Pitt diamond.



It is scarcely necessary to state that drawings may be made from gnomonic as well as from stereographic projections, with but slight modifications of the methods just described.

It is the writer's belief that the average student will find it easier to draw crystals from axes and the symbols of crystal faces, as set forth in the earlier part of this paper, than from the stereographic projection. Cases may arise, however, in which the latter methods may be found useful, as, for example, in finding the intersections between faces of twin crystals, or in representing some odd shapes which can not be referred to the axes of the crystal systems.

Mineralogical Laboratory of the
Sheffield Scientific School of Yale University,
New Haven, Conn., November, 1904.

NOTE.—If any desire to make use of the Engraved Axes, page 43, the Protractor for plotting Crystallographic Axes, page 44, or the Special Triangles, page 58, the writer will be glad to answer any communications and see that the necessary articles are supplied from his laboratory.

ART. VI.—*Anemiopsis Californica* (Nutt.) H. et A. An anatomical study; by THEO. HOLM. (With six figures in the text drawn by the author.)

WITH Bentham and Hooker *Anemiopsis* H. et A. and *Gyrotheca* Desne. are included in *Houttuynia* Thunbg., but they all have been kept separate by Eichler* on account of their floral structures. *Houttuynia* is described as possessing only three stamens opposite the three carpels, while in *Anemiopsis* and *Gyrotheca* the flower has six stamens and three carpels in the former, but four in the latter; the ovary is, moreover, perfectly inferior in *Gyrotheca*. The arrangement of the stamens in *Anemiopsis* is somewhat peculiar, as already described by Payer, there being two in front and two behind the ovary, with one on each side of this; this position of the stamens was, also, observed by the writer in the several inflorescences examined. Furthermore, DeCandolle† has treated our genus as distinct from the others.

Anemiopsis Californica does not seem to be very well known anatomically, and since the writer has lately received some fresh and carefully collected specimens from California through our friend Mr. Thos. H. Kearney, we have examined the plant and offer now the following notes as a small contribution to the knowledge of this peculiar genus.

The thick rhizome is horizontal with several strong and quite fleshy roots; its ramification is monopodial, the apical bud being purely vegetative, while the stolons and flower-bearing stems are all lateral, proceeding from the axils of the leaves, which form an open rosette. While, as already pointed out by Eichler (l. c.), the flowers are destitute of prophylla, such occur at the very base of both the stolons and flower-bearing stems, thus representing clado-prophylla.‡ These leaves are two in number and situated to the right and left of the stems; they are membranaceous, scale-like and prominently carinate, but simply one-nerved. The flower-bearing stems are often branched, there being one terminal and two or three lateral inflorescences preceded by one or two green leaves. The stolons show the same structure, but with vegetative shoots instead of inflorescences.

Considered from an anatomical viewpoint the *Piperaceæ*§ have always attracted a good deal of attention, and they figure

* Blüthendiagramme, vol. ii, 1878, p. 6.

† Prodromus, vol. xvi, 1869, p. 237.

‡ Compare Casimir DeCandolle: Mémoire sur la famille des Pipéracées. (Mém. Soc. phys. Genève, vol. xviii, 1865, p. 234.)

§ The anatomy of the order has been described in Dr. H. Solereder's work: Systematische Anatomie der Dicotyledonen. Stuttgart. 1899, p. 775.

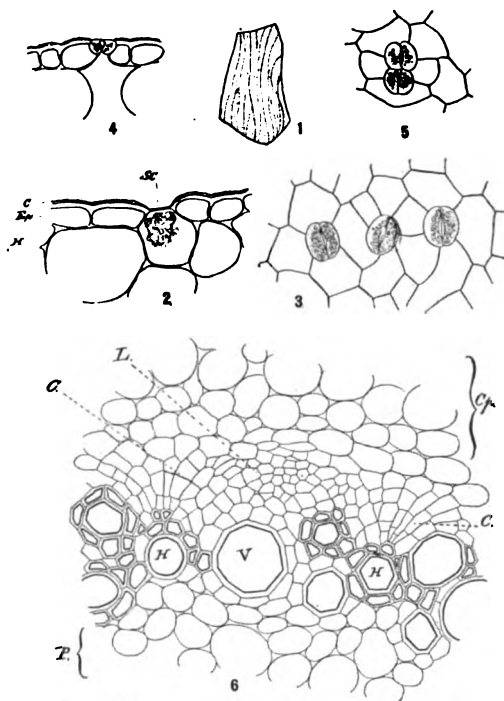
prominently in works upon general anatomy. Not less than four types of stem-structure are described by Dr. Solereder (l. c.), and characteristic of the tribe *Saurureæ*, to which our genus belongs, is one normal ring of collateral mestome-bundles. In regard to the leaf-structure the stomata are said to be confined to the lower surface; in *Anemiopsis*, however, we observed these to be present also on the upper, and even more numerous. Most peculiar is the development of a hypoderm, so very prominent in *Peperomia*, besides the hydathodes. Secreting cells abound in the leaves and stems of both *Pipereæ* and *Saurureæ*, while secreting ducts are only known from some species of *Piper*. Very little seems, however, to be known about *Anemiopsis*, thus we take the opportunity to describe herewith the structure of the various organs in detail.

The leaf-blade.

The cuticle of both surfaces is quite thick and prominently wrinkled, which is especially distinct when we examine the epidermis from above (fig. 1). Epidermis consists of relatively small cells with the outer wall moderately thickened except in the secreting cells (*SC* in fig. 2). For, as may be seen from this figure, secreting cells occur, also, in the epidermis; they are thin-walled throughout, much larger than the ordinary epidermis-cells and sunk below the level of these, thus forming round depressions in the leaf-surface. Long hairs abound on the lower surface and consist of from eight to twelve cells in one row with the cuticle thin and smooth. As stated above, we observed stomata on both surfaces, and they appeared even to be most numerous on the upper; they have no specialized subsidiary cells, but are surrounded by a somewhat indefinite number of ordinary epidermis cells, from four to six, as may be seen from our fig. 3; viewed in transverse sections, the stomata are level with epidermis (fig. 4). A hypoderm of one layer of cells (*H* in fig. 2) is developed on both faces of the blade, but of different structure; the cells are very large and cone-shaped on the upper face with the point towards the palisade-tissue; on the lower face the hypodermal cells are relatively smaller and of a roundish outline (fig. 2).

The leaf is dorsiventral and possesses a distinct palisade-tissue of several layers on the upper face, interrupted here and there by secreting cells; the palisades are rich in chlorophyll and surround the conical, hypodermal cells, but without reaching the epidermis. A pneumatic tissue of irregular, oblong cells, with wide intercellular spaces, occupies the dorsal part of the blade. The mestome-bundles, except the mediane, are small and completely imbedded in the mesophyll; they are surrounded by a colorless parenchyma-sheath. The midrib is

quite broad and projects on the lower surface, where it borders on a large mass of thin-walled, colorless parenchyma. It is composed of seven separate mestome-bundles, each with a parenchyma-sheath and having a support of several layers of stereomatic tissue, especially on the leptome-side.



Anemiopsis Californica.

FIG. 1.—A cell of epidermis from the leaf, showing the wrinkled cuticle, seen from above.

FIG. 2.—Transverse section of the leaf; *C* = cuticle; *Ep* = epidermis; *SC* = secreting cell of epidermis; *H* = hypoderm.

FIG. 3.—Epidermis with stomata of the leaf, seen from above.

FIG. 4.—Transverse section of leaf, showing a stoma.

FIG. 5.—Epidermis with twin-stomata, seen from above.

FIG. 6.—Transverse section of a part of the central-cylinder of the root; *L* = leptome, outside a secondary vessel *V*; *C* = cambial layers; *H* = the primordial rays of hadrome; *P* = pith; *Cp* = secondary cortical parenchyma.

The petiole.

The cuticle shows the same structure as described above; the epidermis possesses stomata, but no hairs, and is rather small-celled. A hypoderm is, also, developed here, but it is uniform and consists only of one layer of roundish cells. The

cortical parenchyma, at least the peripheral strata, contains chlorophyll, and is very open from the great width of the intercellular spaces; secreting cells occur, also, here, but are not very frequent. Separating the cortex from a central group of parenchymatic tissue, a pith, is a circle of twelve collateral mestome-bundles, each with a thin-walled parenchyma-sheath, and surrounded besides by strata of stereomatic tissue. The stereome, however, is confined to the periphery of the mestome-bundles themselves, and does not connect these as a continuous ring of mechanical tissue as is the case with the stem. Characteristic of the mestome-bundles in the petiole is their elliptical outline in cross-section with the leptome, forming a narrow, linear group in contrast to the broad group of hadrome with numerous, narrow vessels.

The prophylla.

As already mentioned, the stolons and flower-bearing stems are axillary; they bear at their base two scale-like, membranaceous fore-leaves, the structure of which is as follows: The cuticle is very distinctly wrinkled on the outer, the dorsal face, but smooth on the inner, the ventral. Epidermis is thin-walled and consists of relatively small cells throughout with neither trichomes or stomata; the outermost portion of the margins is merely composed of epidermis in two layers corresponding to the dorsal and the ventral. The mesophyll is very poorly represented except in the sharp keel; it is quite open and does not contain chlorophyll, neither is it differentiated as a palisade or pneumatic tissue, but constitutes a homogeneous tissue of roundish, thin-walled cells. There is only one mestome-bundle, which is located in the keel; it has a support of two or three layers of slightly thickened stereome and contains mostly leptome.

The involucre.

The involucreal leaves at the base of the inflorescence are very conspicuous, being large and white; they are prominently papillose on the ventral face, each epidermal cell being extended into an obtuse papilla, while the dorsal face is perfectly smooth. Stomata and secreting cells occur in the dorsal epidermis. A hypoderm of large, roundish cells is developed underneath the epidermis on both faces of the involucre. The mesophyll is almost destitute of chlorophyll; it is homogeneous and traversed by wide, intercellular spaces, besides by several very small mestome-bundles.

The floral bracts.

The cuticle and the epidermis exhibit exactly the same structure as observed in the involucre, while the hypoderm is absent

from the ventral face and but slightly differentiated on that of the dorsal. The homogeneous, somewhat open mesophyll contains a little chlorophyll, and about seven very small mestome-bundles are located in the middle of this tissue.

The stem.

The long stolons above ground and the flower-bearing stems show the same structure. They are nearly cylindric, slightly hairy, but perfectly smooth. We notice, also, here a wrinkled cuticle, covering an epidermis of relatively small cells of which the outer wall is distinctly thickened; none of the epidermal cells were transformed into secreting cells. Underneath the epidermis is a hypoderm of only one layer of very large, roundish cells, much larger than those of the adjoining cortex. This tissue, the cortex, consists of about fifteen strata, of which only the peripheral contain chlorophyll; the innermost layer is differentiated as a thin-walled endodermis, surrounding a continuous ring of about fifteen layers of very thick-walled stereome. Directly bordering on the stereome is a circle of twenty-four collateral mestome-bundles separated from each other by broad medullary rays; they are oval in cross-sections and contain both leptome and hadrome, the latter consisting of a few, but wide vessels. But there is no parenchyma-sheath and no mechanical support on the sides of these mestome-bundles or around the hadrome. The central pith is very thin-walled and open. Secreting cells abound in the cortex and in the pith.

The rhizome.

The horizontal rhizome is cylindric, glabrous and smooth; towards the apex it is densely covered with sheathing, green leaves, and is not exposed to the light. Its free portion, behind the rosette of leaves, becomes soon deprived of both the epidermis and hypoderm, but protected by many layers of cork. The cortical parenchyma consists of about fifteen layers with wide intercellular spaces; the cells are filled with starch or contain a secretion of a reddish brown color. The very numerous mestome-bundles are narrow oblong in transverse sections, and are nearly all arranged in a circle separated from each other by rays of the very broad, central pith, which contains starch. The leptome occupies only a small portion of the mestome-bundles, and between this and the very prominently developed hadrome are several strata of cambium.

The root.

All the roots were so far advanced that they showed only a secondary stage of growth. By the increase in thickness the

tissues from epidermis to pericambium had been thrown off and replaced by some, five to six, layers of cork and a very large parenchyma of secondary cortex, filled with starch or sometimes interspersed with secreting cells. Towards the central cylinder the cells of the cortex decrease in size and the innermost layer shows somewhat the structure of a secondary endodermis by its darker color and its power to resist the effect of concentrated sulphuric acid. The central cylinder, however, shows a part of its original structure, viz: a circle of nine short hadromatic rays, each consisting of a few, narrow vessels (*H* in figure 6). These rays alternate with nine collateral mestome-bundles in which the vessels are quite wide (*V* in fig. 6), and mostly more thin-walled than the primordial. Several layers of cambial tissue (*C* in fig. 6) are developed outside the old vessels and inside the groups of leptome, where the secondary hadrome has become developed. A broad and compact pith occupies the inner part of the central cylinder, thus the structure of the root corresponds very well with that of the stem, if it were not for the presence of the primordial rays of hadrome between the collateral mestome-bundles.

Summary.

Being an inhabitant of moist, saline localities our plant may, perhaps, be regarded as a Halophyte. The structural peculiarities of this category of plants has been studied to some extent, but as yet too little has been ascertained to enable us to draw the line between Halophytes and Xerophytes or even the Hydrophytes. Moreover, there are certain orders of plants in which the structural peculiarities appear as characteristic of the order and to some extent inherited, rather than being an expression of a certain mode of adaptation, such as the epharmonic characters.

Now in regard to *Anemiopsis Californica*, it certainly appears as if the structure may be defined more properly as simply "piperaceous" than either halophilous or xerophilous. The most conspicuous characters—the prominently developed hypoderm and the abundance of secreting cells throughout the various tissues—are in conformity with the general structure of the order rather than with the Halophytes, for instance, and these characters are very important. Then when we compare the tables of "leaf-anatomy of salt-marsh species" in Mr. Kearney's interesting paper on this subject,* we notice several points by which our plant differs from his salt-marsh species.

* The plant covering of Ocracoke Island. Contrib. U. S. Natl. Herb., vol. v, Washington, 1900, p. 310.

Most of the species examined by this author possess isolateral leaves; several of these have hypodermal collenchyma or the mestome-bundles are supported by real stereome. On the other hand, Mr. Kearney observed a wrinkled cuticle and a like distribution of stomata on both leaf-surfaces, both of which characters, as we remember, are also to be observed in *Anemiopsis*. A similar result is reached when we compare the species examined by Professor Warming,* none of which possess such striking peculiarities as those characteristic of the *Piperaceæ*, nor do the features of his Halophytes in general agree with those of our plant; only a few points and of no particular interest or of seemingly great importance may be found common to both. As stated by Professor Warming, the lack of stereome seems to be characteristic of the Halophytes, so far as concerns their leaves, and only these have been examined. In this respect *Anemiopsis* would show some likeness to the Halophytes, since the leaves contain very little stereome and only near the midrib. But if we compare the other parts of the plant, the stem and the petiole for instance, we then observe this tissue to have reached a very high development, especially in the flower-bearing stems and the stolons.

It would, thus, appear as if *Anemiopsis* so far as concerns the structure, gives a better illustration of one of the several types of the *Piperaceæ* than of any specialized type modified in accordance with the environment, halophilous for instance.

Brookland, D. C., October, 1904.

* Halofyt-Studier, Kgl. Danske vid. Selsk. Skr., 6th series, vol. viii, Kjöbenhavn, 1897, p. 175.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Production of Pure Sodium Hydroxide for Laboratory Uses.*—On account of the danger in dissolving any considerable amount of metallic sodium directly in water, because of the very violent explosions that are likely to take place from an unexplained cause, even with bright metallic sodium, F. W. KÜSTER has devised a method for effecting this solution slowly by the help of moist air, and has thus obtained a very satisfactory and cheap caustic alkali solution. He places a bell-jar in a large, flat dish in which there is sufficient water to make a water-seal, and under the bell-jar he places a platinum, silver, or nickel dish, crucible, or wide-necked flask, as a receptacle for the caustic solution. Above the receptacle is placed upon a tripod a piece of nickel wire gauze, bent into a conical shape with its apex downward, and in the cone pieces of sodium are placed after the outer crust has been cut off. The sodium begins at once to deliquesce while bubbles of hydrogen escape through the water-seal, and the resulting sodium hydroxide solution drops as a very concentrated, oily liquid from the point of the cone into the dish below. The operation goes on until all the sodium has been used up, and at last certain impurities of the sodium remain upon the wire-gauze, so that this process gives a purer product than direct solution. The solution thus obtained is of about 40 per cent strength, and it may be kept absolutely free from carbonate.—*Zeitschr. anorgan. Chem.*, xli, 474.

H. L. W.

2. *The Production of Magnetic Alloys from Non-Magnetic Metals.*—R. A. HADFIELD, who has produced the well-known non-magnetic alloy of iron and manganese known as "manganese steel," calls attention to the interesting fact that a magnetic alloy can be produced from the non-magnetic metals, copper, aluminium, and manganese. A sample of this alloy, which appears to have been prepared by Dr. F. Heusler, contains 60 per cent copper, 25 to 27 per cent manganese, 12 per cent aluminium, 6 to 7 per cent silicon, 0.5 to 1 per cent carbon and probably 0.5 per cent iron; but samples containing absolutely no iron had exactly the same magnetic properties. It has been found that no alloy of copper and aluminium is magnetic, hence it appears that the magnetic properties of the alloy are due to manganese, which, curiously enough, produces the non-magnetic alloy with iron. It is to be observed, however, that the alloy under consideration requires the presence of a certain amount of aluminium in order that it may be magnetic, and that with fairly constant contents of manganese amounting to 25 to 28 per cent, the maximum "magnetizability" is reached when 14 per cent of aluminium is present.—*Chem. News*, xc, 180.

H. L. W.

3. *Ozobenzol.*—A product of the action of ozone upon benzol

was named and described by Renard a number of years ago, and the formula $C_6H_4O_3$ was then ascribed to it. HARRIES and WEISS have recently re-investigated this substance and find that its formula is $C_6H_4O_3$; that is, three molecules of ozone attach themselves to benzol, presumably at the points of double linking, according to Kekulé's theory. The compound forms a gelatinous mass when ozonized oxygen is allowed to act at $5-10^\circ$ upon benzol. It is fearfully explosive, resembling iodide of nitrogen in this respect. When ice-cold water is placed upon the amorphous substance it assumes a crystalline modification which is also exceedingly explosive. It appears that the formation of this compound is a support to Kekulé's benzol theory.—*Berichte*, xxxvii, 3431.

H. L. W.

4. *Concerning Emanium*.—Some time ago GIESEL announced that he had found a new radio-active substance related to lanthanum, which was characterized by its remarkable action upon the blende screen. He has recently been able to compare the action of this "emanium" with Debierne's actinium, which is related to thorium, and finds that the two substances show no difference with the screen. He is still inclined to believe, however, that there may be a difference in the substances, on account of an apparent slight difference in the rates of decay of their induced activity, and also on account of the fact that three lines which the phosphorescence of his substance shows in the spectroscope have not been found with actinium.—*Berichte*, xxxvii, 2963.

H. L. W.

5. *The School Chemistry*; by ELROY AVERY. 12mo., pp. 423. American Book Company, 1904.—This new text-book for high schools and academies is noticeable for being more extensive in its scope, both in the descriptive and theoretical parts of the subject, than is usual with books of this class. The experiments introduced are numerous, more than 300 being given, and they appear to be very well chosen for the purposes of instruction. A particularly good feature of the book is the number and variety of arithmetical problems, and other thought-inducing questions, that are presented. Although the book is well up-to-date in its facts, since such recent topics as radio-activity are discussed, the treatment of chemical theories may be considered as somewhat old-fashioned. For instance, there appears to be no mention of ionization, although many electrolytic experiments are given, and although the "changing places" of atoms or groups in reactions is frequently alluded to. A few inaccurate or misleading statements have been noticed in the book, but these do not appear to be unduly numerous. It is to be hoped, since hydrogen was solidified several years ago, that the characterization of lithium as the lightest solid known will soon disappear from our text-books, because it is about seven times heavier than solid hydrogen.

H. L. W.

6. *Application of Some General Organic Reactions*; by Dr. LASSAR-COHN. Authorized Translation, by J. BISHOP TINGLE.

12mo., pp. 101. New York, 1904 (John Wiley & Sons).—The topics discussed in this book are "Fixation of Hydrogen Atoms," "Modification of Reactions," "Improvement in Conditions of Reactions," and "Influence of Atoms and Atomic Complexes." These subjects are of importance, and have not received sufficient attention in other works. The simple and entertaining manner in which the book is written should make it of interest not only to the experienced chemist, but also to the beginner in organic research.

T. B. J.

7. *Influence of Glass Walls of Geissler Tubes on Stratified Discharges in Hydrogen*.—E. GEHRCKE, of the Reichsanstalt, finds that the glass walls exert a marked influence on the length of such stratifications. Not only the curves drawn from measurements but the appearance of the stratifications in suitable tubes show this influence. To make the effect evident to the eye one side of the inner wall of a Geissler tube was covered with silver; this had the effect of changing the length of the stratifications. The inner walls were also covered in another case with a layer of phosphoric pentoxide, with the same result. The author refers the stratifications observed in open space in flames to an effect of secondary cathodes. The stratifications in Geissler tubes appear to be a chain of cathodes with dark spaces and light spaces; the potentials of which seem to form an arithmetical series, and each stratification hands on to the next as much negative electricity as it received from the previous one. Foundation for a suitable mathematical theory is discussed.—*Ann. der Phys.*, No. 13, 1904, pp. 509-530.

J. T.

8. *Phosphorescence*.—P. LENARD and V. KLATT continue their researches on this subject. Among their interesting conclusions is the following: Stokes's law that the waves of excited light are always longer than those of the exciting light has not been sustained by analysis of the sixty-four fluorescent bands examined. If the range of the exciting and the produced light are compared, it is seen that the exciting light and the fluorescent bands often approach each other very nearly; sometimes coincide, but never overleap each other. Study was made of momentary and more or less permanent fluorescence and of their dependence on exciting conditions.—*Ann. der Phys.*, No. 13, 1904, pp. 425-484.

J. T.

9. *Color Changes in Gold Preparations*.—The theory of electrical resonance has been applied by various observers to account for the phenomena presented by colloidal preparations of gold in reference to color. F. KIRCHNER and R. ZSIGMONDY have had in view especially Planck's work in this direction. Their results support in general Planck's theory. There were, however, noticeable lacunæ between the theory and the observations.—*Ann. der Phys.*, No. 13, 1904.

J. T.

10. *Spectra of Hydrogen, Helium, Air, Nitrogen, and Oxygen in the Ultra Violet*.—With the aid of a quartz spectroscope, J. SCHNIEDERJOST has made a study of these gases. Comparison lines of platinum were employed. Two new lines of helium at

wave-lengths 2653·1 and 2644·9 were discovered which belonged to the first main series. Deslandres' nitrogen group which lies between wave-lengths 3009·6 and 2205·3 was investigated, and Deslandres' results confirmed. Seventy new lines of the line-spectrum of nitrogen were also measured. A number of new lines of oxygen were also discovered.—*Diss. Halle*, 1904. *Beiblätter*, *Ann. der Phys.*, No. 22, 1904. J. T.

11. *Pressure of Light*.—In a sealed communication to the R. Accad. dei Lincei in 1882, opened at the meeting of February 1, 1903, A. BARTOLI relates that certain experiments conducted in the year 1876 appeared to show that the pressure of light apparently confirmed by late experimenters does not really exist, and that there arises a certain resistance which a reflecting body encounters in a region of radiation, and which in the movement of a reflecting body would be shown in the body without a normal component in consonance with the second law of thermodynamics. He suspects further that the work for overcoming this resistance is changed into electric currents in the reflecting metal. These currents should be of measurable size. This suspicion was apparently confirmed by experiment. He mounted a strong circular disc upon the axis of a solid lathe. This disc had a circular highly-reflecting band which was insulated by dry wood soaked in oil. The band was cut and the two ends were connected to two rubbing insulated contacts and to a sensitive galvanometer. The velocity of revolution of a point on this band was 240–410 meters per second. When sunlight fell on the silvered band the thermo-electric effect was only 2·3^{mm} deflection if the disc was at rest. When the disc rotated in the dark there was no reflection. As soon as sunlight fell on the rotating disc the galvanometer gave a deflection of 42^{mm}, and this deflection persisted while the sunlight remained. It disappeared when the sunlight was removed. When the revolution was reversed the deflection was reversed to –32^{mm}. A half speed gave a deflection of 20^{mm}. These experiments were made in August and September, 1880, in the Technical Institute of Florence, and were so far as is known never resumed.—*Beiblätter*, *Ann. der Phys.*, No. 22, 1904. J. T.

12. *Notes on X-Light*; by WILLIAM ROLLINS. Pp. 400, plates 150, Boston, 1904.—This beautifully printed volume contains the arduous researches of a professional man who has devoted his evenings to what is perhaps the most baffling and trying of all physical research, experimentation on gases at low vacuo—trying both to physical endurance and to the spirit; for just as nature seems to be inclined to open her mysterious chambers, the glass apparatus and the mechanical apparatus employed in producing such vacuo breaks, and the course of experimentation has to be begun anew. The expenditure of time and money, in giving freely to physicians and surgeons the best means of producing and employing the X-rays, shown by this book is remarkable, especially when one reviews the history of the use of these rays and sees the endless effort to secure all

improvements in tubes or processes of regulation by patents. Following the method adopted by Faraday, the author relates both positive and negative results of his experiments. In the subject of rarified gases, especially at low pressures, this method in the present uncertainty of our knowledge is most useful; for, like the story of the Alpine climber who relates his attempts to scale some most difficult aiguille, it stimulates the imagination and leads to a consideration of all possible paths in the hope of finding, even through failure, a way to the summit; and in ultimate success, the first path-breaker should not be forgotten. In reading the list of contents of this volume one is surprised at the richness of suggestion. Every form of X-ray tube, of regulators and of excitors for such tubes, receives thought, and it is recognized by those who have followed Dr. Rollins' work that the present forms of the most enduring and most efficient tubes are the result of his work. Makers of such tubes have eagerly taken up his suggestions and by (we will charitably say) unconscious cerebration have taken credit to themselves. This is true also of the open construction of Ruhmkorf coils which the author fully describes in his book, and the employment of a hinged Faraday ring in the primary of such coils. This is a most efficient construction of a transformer both for X-ray work, for spectrum analysis, and for wireless telegraphy. No one in America appears to have had the experience of Dr. Rollins in exhausting X-ray tubes to their point of greatest efficiency. He points out many phenomena of absorption and occlusion of gases by the various terminals he employed, and by the glass walls of the enclosure which are now being studied quantitatively by various observers. This occlusion or absorption can under certain conditions reduce the pressure in an X-ray tube from one-thousandth of a millimeter to one two-thousandth. The mechanical skill shown in the plates of appliances for the employment of X-rays in surgery, which are collected at the end of the volume, would suffice alone to make this a notable work and a monument of altruism.

J. T.

II. GEOLOGY AND MINERALOGY.

1. *Indiana Geological Survey*.—W. S. BLATCHLEY, State Geologist. 28th Annual Report, 1903, 553 pp., with plates, maps and figures.—In addition to the statistical reports of the mine inspector, the gas supervisor, etc., the Indiana Survey Report for 1903 contains articles by T. C. Hopkins and A. F. Foerste on the Topography and Geological Formations of the state accompanying the new Geological Map; and a paper on the Stratigraphy and Paleontology of the Niagara, by E. M. Kindle. There is also a valuable table of contents of all of the geological literature published by the state of Indiana. The report of the state gas supervisor brings clearly to mind the great waste that has been caused by the careless treatment of the natural gas supply. The people of the state have finally been convinced that the gas sup-

ply is not inexhaustible. It is fast declining and the end is not far off. Most of the present drilling is done in territory abandoned years ago, and the average well now drilled would have been considered a failure ten years ago. The price of gas has increased fivefold in ten years and at the present time more pipeline is being taken out of the ground than put in it. Two large gas companies have entirely abandoned the city of Indianapolis.

2. *Geological Map of Indiana*. — A new geological map of Indiana has been published under the direction of W. S. Blatchley, state geologist, on a scale of four miles to the inch. This map is a compilation of all the stratigraphic work done in the state from 1895 to 1903 inclusive, while the actual work of preparation is by T. C. HOPKINS. Accompanying the map is a short description (77 pp.) of the topography of Indiana and of the chief geologic formations of the state. No attempt has been made to represent the rock structure underneath the heavy glacial deposits covering the northern part of the state for a distance of about forty miles.

3. *Geological Survey of New Jersey*; HENRY B. KÜMMEL, State Geologist. Vol. VI, 533 pp., 56 pls., 41 figs.—The latest volume of the New Jersey survey deals with the Clays and Clay Industry of New Jersey, and is written by Heinrich Ries and H. B. Kümmel, assisted by G. N. Knapp. The report deals with the occurrence, chemical and physical properties of clays, the stratigraphy of the clays and the method of their manufacture. A very complete set of fire brick tests has been made, particularly in reference to its refractoriness. A striking commentary upon the efficiency of the New Jersey survey is the fact that the clay maps of 1878 are found to be accurate in spite of the great development of the industry since that time.

4. *Recent Seismological Investigations in Japan*; by Baron DAIROKU KIKUCHI, Emeritus Professor of Mathematics Tōkyō Imperial University, Member and former President of the Imperial Earthquake Investigation Committee. Pp. ix + 120. 54 illustrations. Tokyo, 1904.—This volume, stamped "for private circulation only," was distributed at the Japanese exhibit of the recent exposition in St. Louis. As stated in the introduction, Japan is preëminently the land of earthquakes, and following the great Mino-Owari earthquake of October, 1891, in which over 7000 people were killed, the Imperial Earthquake Commission was established with a twofold object. First, to investigate whether there are any means of predicting earthquakes; and, secondly, to determine how to reduce the disastrous effects to a minimum. With characteristic Japanese insight and thoroughness the commission decided that the best way to attain its objects was first, possibly for many years, to study earthquakes in every relation, even such as might appear to have little or no bearing upon the immediate objects. The results of these investigations are given in sixteen publications in foreign languages, a list of which is given in the back of this volume. Among the more

noticeable features of the present volume are charts giving the time, distribution and periodicities of Japanese earthquakes for over a thousand years, and studies in the variations in magnetism, latitude and other physical changes as possibly having relations with the occurrence of severe earthquakes. For more than a decade astronomers have been familiar with the fact, rendered evident by long continued and refined astronomic observations in several parts of the world, that the earth's axis of rotation is not absolutely fixed, but that, on the contrary, the poles wander through a period of years in a complex path within a circle of a few hundred feet radius. Among other results the commission has found that the seismic activity of Japan presents a period of six and one-half years, and in the past nine years all the destructive earthquakes occurred exactly or very nearly when the latitude was at a maximum or minimum. J. B.

5. *Earthquakes, in the Light of the New Seismology*; by CLARENCE EDWARD DUTTON, Major U. S. A. Pp. xxiii+314, with 63 illustrations. New York (G. P. Putnam's Sons), London (John Murray), 1904.—This is volume 14 of "The Science Series," and while clear and readable throughout, nevertheless enters into all the chief problems related to earthquakes and is a volume which should be read by every teacher of physical geology. Previous to 1870 the studies published were with few exceptions little more than narratives of disasters. Since that time, largely through the labors of Ewing and Milne, who have more recently been joined by many other investigators, the subject has grown into an exact science which not only reveals the location of regions of instability whether at the antipodes or even under the ocean, but which is throwing light upon such problems as the density and solidity of the earth's interior.

After discussing the nature and causes of earthquakes, the author devotes 48 pages to the subject of earthquake instruments, obviously an important topic since it is from these refined instruments that nearly all of our modern knowledge has come. Following this are 119 pages on the nature of earthquake waves and the deductions from them. This statement gives some idea of the complexity of the record and the involved messages it brings from the earth's interior and which are still far from being completely understood. The last part of the book discusses earthquake distribution and seaquakes. J. B.

6. *Minerals of Japan*; by TSUNASHIRO WADA, translated by TAKUDZI OGAWA. Pp. 144 with thirty plates. Tokyo, 1904.—Notwithstanding the comparatively limited extent of Japan and the fact that its resources are as yet only partially developed, the country has afforded a large number of mineral species, many of them of peculiar interest either because of their rarity or of the beauty of their crystallization. The volume before us gives an excellent summary of this subject and deserves careful study by all interested. Concise accounts of the species identified are given, with exact statement of locality and numerous analyses; a series

of fine heliotype plates give representations of notable specimens, for example, of the well known quartz twins, also the fine sibnite and topaz crystals. Among other Japanese minerals of especial interest may be mentioned crystallized danburite containing a considerable amount of magnesia (7.67 p. c.); datolite at Nobori, Hyuga Pr.; chalcopyrite of varied and unusual habit; axinite, etc. A new species, *naëgite*, is also described, as noted below.

7. *Brief notice of some recently described Minerals*—**NAËGITE** is a new silicate of uranium and thorium collected with fergusonite from the placer tin washings near Takayama, Mino province; it is described by T. Wada on p. 49 of the *Minerals of Japan* (1904, see above). It occurs in small spheroidal aggregates, also rarely in small crystals of pseudo-dodecahedral habit; these are probably tetragonal and isomorphous with zircon. The color varies between dark pistachio-green, greenish gray and brown or reddish brown; under the microscope it is transparent, grass-green and highly refractive, though also often nearly isotropic. The hardness is about 7.5 and the specific gravity 4.09; it has marked radio-activity. An analysis by T. Tamura afforded:

SiO ₂	UO ₂	ThO ₂	Ta ₂ O ₅	Nb ₂ O ₅	CeO ₂	Fe ₂ O ₃	CaO	MgO	H ₂ O	
34.89	28.27	16.50	7.00	4.10	1.59	1.60	1.71	0.57	3.12	= 99.35

The name is from the locality where the new mineral has been found, viz. Naëgi near Takayama.

TEALLITE is a new sulpho-stannate of lead from Bolivia, exact locality unknown; it is described by G. T. Prior. It occurs in thin inelastic, flexible and cleavable folia showing crystals face on the edges; the angles afforded by these proved that the mineral is orthorhombic and somewhat related in form to nagyagite. The hardness is 1 to 2 and the specific gravity 6.36; luster metallic, color blackish gray, streak black. The mean of two analyses gave: S 16.29, Sn 30.39, Pb 52.98, Fe 0.20 = 99.86. This yields the simple formula PbSnS_2 , or $\text{PbS} \cdot \text{SnS}_2$. Teallite is named after Dr. J. J. Harris Teall, Director-General of the Geological Survey of Great Britain and Ireland.

The same author has also analyzed carefully selected samples of franckeite and cylindrite, both from Poopó, Bolivia, the locality from which teallite may also very probably have been derived. The result is to give for franckeite the formula $\text{Pb}_2\text{FeSn}_2\text{Sb}_2\text{S}_{11}$, or $3 \text{ PbSnS}_2 \cdot \text{Pb}_2\text{FeSb}_2\text{S}_8$; for cylindrite, $\text{Pb}_2\text{FeSn}_2\text{Sb}_2\text{S}_{11}$, or $3 \text{ PbSnS}_2 \cdot \text{SnFeSb}_2\text{S}_8$. *Min. Mag.*, xiv, pp. 21-27, Oct. 1904.

PALMERITE is a new hydrated phosphate of aluminium and potassium described by Eugenio Casoria from a deposit of guano found in a large cavern at Monte Alburus near Controne, province of Salerno, Italy. It occurs in a white, amorphous pulverulent form, unctuous to the touch and resembling purified kaolin. An analysis yielded:

P ₂ O ₅	Al ₂ O ₃	K ₂ O	Na ₂ O	H ₂ O(100°)	ign.	Fe ₂ O ₃	NH ₃	SiO ₂	
37.10	22.89	8.04	00.3	7.87	21.29	1.17	0.61	0.37	= 99.37

The calculated formula is $\text{HK}_2\text{Al}_2(\text{PO}_4)_3 + 7\text{H}_2\text{O}$. *Att. Accad. Georgofilè* (5), i, July 3, 1904.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Annual Report of the Regents of the Smithsonian Institution*, S. P. LANGLEY, Secretary, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1903. Pp. lxi, 376 with 124 plates. Washington, 1904.—This volume contains the usual account of the administrative activity of the Smithsonian Institution in its different directions. The work in one of these in particular, the International Exchange Service, is presented in a very interesting form. In an Appendix a striking exhibit is made of the extent to which this service has been developed; upwards of 150,000 packages were sent out to all parts of the world between July, 1902, and June, 1903, this work having nearly doubled in six years. The value of this service to the science of the country can hardly be overestimated. Another Appendix describes the additions to the National Zoological Park, with some interesting illustrations; still another gives a report of the work of the Astrophysical Observatory for the year ending June 30, 1903. It is interesting to note here that the bolographic work carried on showed the earth's atmosphere to have been more opaque than usual, the direct solar radiation having been reduced about 10 per cent on an average through the entire spectrum. It is also shown to be probable that the radiation has been decreased outside of the earth's atmosphere. A new determination of the temperature of the sun, based upon the distribution of the solar radiation in the spectrum, has yielded the result of $5,290^{\circ}$ Centigrade above the absolute zero. As usual, the larger part of the volume of about 800 pages is given to the republication of a well-chosen series of scientific papers, showing the progress made in all departments of science. These are fully illustrated and form a most interesting series, which ought to be accessible to all intelligent people.

2. *Bulletin of the Bureau of Standards*; S. W. STRATTON, Director. Vol. I, No. 1, pp. 124. Washington, 1904 (Department of Commerce and Labor).—The Bureau of Standards, established some four years since, in addition to its regular testing work, the value of which is now thoroughly appreciated in the country, has recently undertaken the publication of occasional Bulletins. These will contain the results of investigations and researches carried on in connection with the Bureau, and which are likely to be of general interest in the country, either on the scientific or technical side. The Bulletins will be issued as often as they are required to present papers which are ready for publication. The first number, issued November 1st, contains eight articles. L. A. Fischer discusses a recomparison of the United States prototype meter; K. E. Guthe gives a study of the silver voltameter, and also describes fibers resembling quartz made from asbestos (amphibole) and steatite; F. A. Wolff discusses the so-called international electrical units; P. G. Nutting has papers on the spectra of mixed gases, on secondary spectra, and

on new rectifying effects in conducting gases; C. W. Waidner and G. K. Burgess give results of determinations of the temperature of the arc varying from 3690° to 3720° C., according to the form of pyrometer employed.

3. *National Academy of Sciences*.—The autumn meeting of the National Academy was held in the buildings of Columbia University, New York city, on November 15 and 16. The following is a list of papers presented:

W. K. BROOKS: On the affinities of the Pelagic Tunicates.

W. K. BROOKS and S. RITTENHOUSE: The life history of *Turritopsis*.

W. K. BROOKS and R. P. COWLES: *Phoronis architecta*, its anatomy, life history, and branching habits.

JOHN TROWBRIDGE: On the electrical resistance of a vacuum.

FRANZ BOAS: Psychic associations in primitive culture.

M. I. PUPIN: Time electrical impulses.

C. BARUS: The occurrence of maxima and minima of atmospheric nucleation in approximate coincidence with the winter and summer solstices respectively.

L. A. BAUER: The system of magnetic forces causing the secular variation of the earth's magnetism.

R. H. CHITTENDEN: The influence of low proteid metabolism on the formation and excretion of uric acid in man.

EDWARD M. MORLEY: Note on the theory of experiments to detect the second power of the aberration of light. Also, Report of a repetition of the Michelson-Morley experiment on the drift of the earth through the luminiferous ether.

C. S. PEIRCE: On topical geometry.

N. YATSU: An experimental demonstration of the formation of centrosomes *de novo*.

T. H. MORGAN: An analysis of the phenomena of organic polarity.

E. B. WILSON: Experiments on prelocalization in the annelid ovum.

C. E. MENDENHALL: The absolute value of the acceleration of gravity determined by the ring-pendulum method.

R. S. WOODWARD: The double suspension pendulum for measuring the acceleration of gravity.

THEO. HOLM: The genus *Claytonia*,—morphological and anatomical studies.

CHARLES S. HASTINGS: A determination of the dispersive power of the human eye.

CHAS. F. CHANDLER: The air in the Subway in New York.

W. H. DALL: Biographical memoir of Charles Emerson Beecher.

EDGAR F. SMITH: Biographical memoir of Robert E. Rogers.

4. *American Association for the Advancement of Science*.—The fifty-fourth annual meeting of the American Association was held in Philadelphia, in the buildings of the University of Pennsylvania, during the week from Dec. 27 to 31. The various affiliated societies also held their meetings at the same time and place. This is the third "Convocation week" that has been observed at this season of the year.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VII.—*The Isomorphism and Thermal Properties of the Feldspars*; by ARTHUR L. DAY and E. T. ALLEN.
(With Plate I.)

THE investigation here recorded is the first chapter in a rather comprehensive plan for the study of the rock-forming minerals at the higher temperatures. In its broader outlines at least, it is by no means a new plan. Mr. Clarence King and Dr. George F. Becker were inspired by a desire to reach the mineral relations from the experimental side, which is recorded in the very earliest records of the U. S. Geological Survey, and much of the remarkable ground-breaking work of Professor Carl Barus was undertaken in furtherance of a carefully prepared scheme of research along these lines. The matter has been advanced but little in the intervening years. The present renewal of the effort in this direction is again due to Dr. Becker and has the benefit of his wide field experience and enthusiastic and effective coöperation throughout.

In October, 1900, one of the authors was called from the Reichsanstalt to equip a laboratory in the U. S. Geological Survey in which the exact methods and measurements of modern physics and physical chemistry should be applied to the minerals. The ultimate purpose was geological, to furnish a better basis of fact for the discussion of the larger problems of geology, but it appeared highly probable also that a quantitative study of the thermal phenomena in this class of substances would offer new relations of intrinsic interest and of considerable theoretical value. This inference has been happily substantiated quite recently through the publication by Tammann of an extended treatise on melting and crystallization,* in which

* Tammann, "Krystallisiren und Schmelzen." Leipzig, 1903.

he offers some very interesting speculations on the conditions of equilibrium for substances above and below the melting temperature under different pressures. The behavior of crystalline minerals, which melt at temperatures considerably higher than he was able to command, offers peculiarly advantageous opportunities for verifying the truth of his inferences and of contributing further to the knowledge of this most important change of state of matter.

Temperature Measurements.—It is only a short time since it became possible to measure even moderately high temperatures with certainty and to express them in terms of a well-established scale. Temperature is a peculiar function in that it is not additive. Two bodies, each at a temperature of 50° , can not be united to obtain a temperature of 100° , nor can any number of bodies, at a temperature of 50° or below, give us information about the temperature 51° or above. Furthermore, temperature is not independently measurable: we can only measure phenomena like the expansion of gases or the conductivity of platinum wire or the energy of thermal radiation, which we have good reason to suppose will vary with the temperature uniformly or according to a known law.

The measure of temperature now generally accepted as standard is the expansion of hydrogen gas between the melting point of ice and the normal boiling point of water, divided into 100 equal increments or degrees. Temperatures above this point* have been determined by continuing the expansion of hydrogen or nitrogen in the same units, as far as it has been found possible to provide satisfactory containing vessels for the expanding gas. Such determinations are then rendered permanent and available for general use by establishing fixed points, such as the melting temperatures of easily obtainable pure metals, at convenient intervals. Beyond 1150° no trustworthy gas measurements have been made and we have therefore no standard scale. For higher temperatures it is usual to select some convenient phenomenon which is measurable up to the temperature desired, to compare it with the gas scale as far as the latter extends and then to continue on the assumption that the law of its apparent progression below 1150° will continue to hold above that point. In this way we obtain degrees which, if not identical with the degrees of the gas scale, approximate very closely to them and can receive a small correction if necessary, whenever the gas scale shall be extended or another scale substituted.

* To 600° , Chappuis et Harker, *Travaux et mémoires du bureau international des poids et mesures*, xii, 1902. To 1150° , Holborn and Day, *Ann. der Physik*, ii, 505, 1900; English translation, this Journal [4], x, 171, 1900.

The application of measurable high pressures at the higher temperatures has never been successfully accomplished, and until something can be done in this direction, our knowledge of the rock-forming minerals and in fact all the generalizations relating to equilibrium between the states of matter, which have been established for moderate temperatures, must be regarded as more or less tentative and subject to eventual revision. We have been accustomed to assume, both in geology and physics, with rather more confidence than scientific experience justifies, that established relations for ordinary temperatures and pressures will hold in comparable ratio for the higher temperatures and pressures also. Experimentation under extreme conditions is slow and technically difficult, and it is therefore not strange that simple relations which are verifiable within easily accessible conditions should now and then be accorded the dignity of natural laws without sufficient inquiry into the more remote conditions.

General Plan.—Our plan on entering this field was to study the thermal behavior of some of the simple rock-making minerals by a trustworthy method, then the conditions of equilibrium for simple combinations of these, and thus to reach a sound basis for the study of rock formation or differentiation from the magma. Eventually, when we are able to vary the pressure with the temperature over considerable ranges, our knowledge of the rock-forming minerals should become sufficient to enable us to classify many of the earth-making processes in their proper place with the quantitative physico-chemical reactions of the laboratory.

Relation to Geological Research.—The relation which this plan bears to general geological research may perhaps be expressed in this way. Geological field research is essentially a study of natural end-phenomena, of completed reactions, with but a very imperfect record of the earlier intermediate steps in the earth-making processes. The records of the splendid laboratory experiments in rock synthesis which have already been made are also of this character. The final product has been carefully studied, but the temperatures at which particular minerals have separated out of the artificial magma, and the conditions of equilibrium before and after such separation, have not been determined. In fact, except for a limited number of determinations of the melting points of natural minerals, no exact thermal measurements upon minerals or cooling magmas have been made; and it is in this direction that a beginning is to be attempted. The temperatures of mineral reactions under atmospheric pressures are nearly all within reach of existing laboratory apparatus and methods.

Existing Methods.—Furthermore, the methods which have been used in determining these mineral melting points seem to the authors to be open to serious objection both in principle and in application. They depend, almost without exception, upon the personal judgment of the observer and not upon the actual measurement of any physical constant. For this reason perhaps more than any other, the results obtained by different observers upon the same mineral from the same source do not agree within considerable limits, much larger than can be properly ascribed to impurities in the specimens. Familiar examples will best illustrate this point. Among the determinations of the mineral melting points, two have received much more general acceptance than others;—those of Joly* and of Doelter.†

The melting temperatures which they obtained for some of the typical feldspars are as follows:

	Meldometer Measurement.		Thermoelectric Measurement. Gas Furnace.	Thermoelectric Measurement. Electric Furnace.
	Joly, 1891; Cusack, 1896.		Doelter, 1901.	Doelter, 1902.
Microcline	1175°	1169°	1155°	1155°
Albite	1175	1172	1103	1110
Oligoclase	1220		1110	1120
Labradorite	1230	1235	1119	1125
Anorthite			1110	1132

The determinations agree in recording higher melting points toward the calcic end of the series, but the differences between corresponding melting points by the two methods is greater than the observed differences between different feldspars.

Joly's method was novel. He stretched a thin strip of carefully prepared platinum foil between suitable clamps, placed a few grains of the powdered mineral upon it and mounted a small microscope above, so as to be readily trained on any part of the strip. The foil was then heated by an electric current which could be very gradually increased, and the temperature measured from the linear expansion of the strip at the moment when the observer at the microscope noticed the first signs of melting. The author of this method was able to obtain concordant results with it to within about 5° C., but differences several times greater than 5° appeared in the observations made by one of us† with the Joly apparatus, unless the grains were prepared with the greatest care and all the observations made by the same observer. The size and form of the grains, the care used in locating them exactly in the middle of the

* J. Joly, Proc. Royal Irish Acad., iii, 2, p. 38, 1891. R. Cusack, Proc. Royal Irish Acad., iii, 4, p. 399, 1896.

† C. Doelter, Tschermak, Min. u. Petr. Mitth., xx, p. 210, 1901; xxi, p. 28, 1902.

‡ Day.

strip, every draught of air, but most of all the judgment of the observer as to when the substance appeared to melt, all entered into the result to a very considerable degree. And there is another source of error with which we afterward became familiar, which may serve to account for the very large differences between Joly's results and our own later values with some of the well-known minerals, though not with all. In certain of the minerals, after melting, the resistance to change of shape due to viscosity is of the same order of magnitude as that due to the rigidity of the crystal just before melting, a fact which may well have led to large errors of judgment in this method of detecting melting points.

The possibility of working very expeditiously with minute quantities of a substance led us to study this method with great care, and we were fortunate enough to possess an instrument of Prof. Joly's own model made by Yeates & Son, Dublin, but the results obtained with it, even under most favorable conditions, are more in the nature of personal estimates than of exact measurements of the change of state. Its value for qualitative study, and in cases where only a very minute quantity of a substance is available, is unquestioned.

Doelter has employed electric furnaces modeled after that in use at the Reichsanstalt by Holborn and Day for the determination of the melting points of the metals, measured his temperatures with thermoelements, and used several grams of material in his determinations, but he also judged of the approach of the melting point by the appearance of the charge and usually recorded two temperatures, the first approach of viscous melting, and the point where the material appeared to become a thin liquid.

Detailed Plan.—We determined from the first to get rid of this personal factor. However carefully such observations may be made, and however well supported by the reputation of a particular scientist for skillful and exact work, they can not have a permanent value. Melting points of pure minerals are not different, in principle at least, from the melting points of other chemical compounds or of metals. They occur at less accessible temperatures and involve some complicating phenomena, as we shall see presently, but the change of state of a solid crystalline mineral to a liquid must of course be defined by an absorption of heat. Whether the appearance of the mineral charge in the furnace will offer a trustworthy index through which to locate this absorption, may well be expected to differ with different substances. Nearly all observers have recorded the fact that many substances of this class remain very viscous after melting and that the transition is not well marked in the appearance of the material.

We therefore planned an apparatus* which should be as sensitive as possible to heat changes over a long range of temperatures, and then prepared to examine the thermal behavior of simple minerals of natural or artificial composition when gradually heated or cooled. Changes of crystalline form (*Umwandlungen*) or of state (melting and solidifying) must involve a more or less sharply marked absorption or release of heat and be recorded as breaks in a smooth curve in the same way as in the determination of metal melting points or the singularities of any of the well-known chemical compounds at lower temperatures.

First Group of Minerals Investigated.—The particular group of minerals chosen for the first investigation was the soda-lime feldspar series, and orthoclase (microcline). The reasons for this choice will be fairly obvious. Aside from its being altogether the most important group of rock-forming minerals, unusual interest has been attracted to it through Tschermak's theory that these feldspars bear a very simple relation to one another, that they are (orthoclase excepted of course) in fact merely isomorphous mixtures of albite and anorthite. This hypothesis has given occasion for serious and extended study both from the optical and thermal sides.

A complete review of the literature of the feldspars will not be attempted here. Although opinion is still somewhat divided,† it is probably fair to say that the optical researches have failed definitely to establish or disestablish the isomorphism of the albite-anorthite group, and that it is somewhat uncertain whether conclusive evidence will be obtained by optical means alone. Investigation from the thermal point of view has been even less satisfactory by reason of the subjective methods employed, to which reference has already been made, though the recorded results indicate with reasonable unanimity that the melting point of anorthite is above that of albite and that the intermediate feldspars will probably fall between the two.‡ Beyond this conclusion, the great body of evidence is more or less contradictory and sometimes controversial in character.

Orthoclase (preliminary).—Somewhat unluckily, our measurements began with natural orthoclase (microcline) from

* For a detailed description of this apparatus see Day and Allen, *Phys. Rev.*, xix, p. 177, 1904.

† Fouqué et Lévy, *Synthèse des Minéraux et des Roches*, p. 145, 1882. C. Viola, Tschermak's *Min. u. Petr. Mitth.*, xx, p. 199, 1901. Lane, *Journ. Geol.* XII, ii, p. 83, 1904. J. H. L. Vogt — *Die Silikatschmelzlösungen*. Christiania, 1903.

‡ J. H. L. Vogt, loc. cit., p. 154, expresses the opinion that the soda-lime feldspars will be found to fall under Type III of Roozeboom's types of isomorphous series, with a minimum between anorthite and albite. (See p. 134, seq.)

Mitchell Co., North Carolina, a quantity of which was placed at our disposal by the U. S. National Museum. The material was powdered so as to pass readily through a 100-mesh sieve, and placed in 100^{cc} or 125^{cc} platinum crucibles, sometimes open and sometimes covered, in charges of from 100 to 150 grams. These charges were heated slowly in the electric furnace from 600° to above 1400° C., but, although the thermal apparatus was sufficiently sensitive to detect an unsteadiness of a tenth of a degree with certainty, not the slightest trace of an absorption or release of heat was found. The charge at the beginning of the heating was a dry crystalline powder, which was prodded from time to time with a stout platinum wire to ascertain its condition as the heating progressed. At about 1000° traces of sintering were evident, at 1075° it had formed a solid cake which resisted the wire, at 1150° this cake had softened sufficiently to yield to continued pressure and at 1300° it had become a viscous liquid which could be drawn out in glassy, almost opaque threads by the wire. Under the microscope the opacity was seen to be due to fine, included bubbles, the material being entirely vitreous. The cooling was equally uninformative; the vitreous mass solidified gradually without recrystallization or the appearance of any thermal phenomenon. Frequent repetition with fresh charges and varied conditions added nothing to our knowledge of the melting temperature, and the matter began to look very unpromising.

We also reheated charges of the resulting glass which was sometimes repowdered and sometimes in the cake as it had cooled. But except to observe that the glass powder began to sinter earlier (800°), no new facts appeared.*

Then we tried by various means to recrystallize the melted orthoclase. We mixed crystalline powder with the glass, we applied successive quick shocks to the cooling liquid for several hours with an electric hammer below the crucible, we varied the rate of cooling and even tried rapid see-sawing between 800° and 1300°. We circulated air, water vapor, and carbonic dioxide through the charge throughout the heating, and finally introduced a rapid alternating current sent directly through the substance while cooling, but no trace of crystallization resulted. An extremely viscous, inert mass always remained which gradually hardened into a more or less opaque glass. It appeared somewhat translucent if very high temperatures had been reached, but was never clear.

Following orthoclase, a number of specimens of natural albite were tried under similar conditions and with entirely similar results.

* These sintering temperatures varied within considerable limits with the fineness of the material and therefore serve only in a very rough way to define the state of the charges.

Later on, when more experience had been acquired, these minerals were taken up again and a satisfactory explanation for their behavior was found. But for the moment all the defining phenomena appeared to be so effectively veiled by some property, presumably the viscosity, that we were constrained to look about for some simpler compound which should give us a better insight into the behavior of mineral glasses and their thermal relations, and to lay aside the feldspars until they could be more successfully handled.

This outline of our unsuccessful experiences is given here in some detail, in order to show the actual difficulties which confront the student in working with the feldspars, in the face of which it is certainly not surprising that uncertain and contradictory conclusions have been reached.

Borax.—The substance chosen for this preliminary work was ordinary anhydrous borax (sodium tetraborate). We chose this merely because it was a simple glass and unlikely to undergo chemical change. It is easily obtainable pure and its thermal phenomena are within easy reach. The study of borax proved to be most instructive. It gave us an effective insight into the behavior of this class of substances, and in particular served to define the phenomena of melting and solidifying in substances which undergo extreme undercooling and which recrystallize with difficulty or not at all. The results of this study of borax were therefore of much interest in themselves and were given in a paper before the National Academy of Sciences at its spring meeting in Washington last year (April 21, 1903), but were not printed at that time.

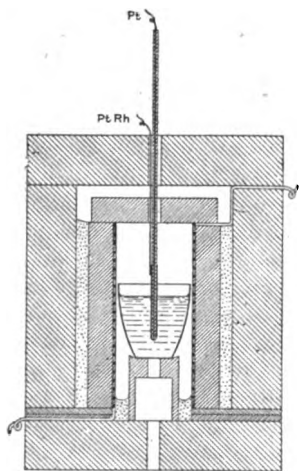


FIG. 1.

tropic, of conchoidal fracture, and specific gravity 2.37. The specific gravity was determined in the fraction of kerosene boiling above 185° C. About 100 gr. of this glass were then broken up and placed in a platinum crucible in the electric furnace. The thermoelement was placed in position

as indicated in fig. 1, the heating current properly regulated and observations of the temperature made at intervals of one minute, while the glass softened and passed gradually over into a thin liquid (800°). Then the current was reduced and the cooling curve observed in the same way. These observations gave an unbroken curve both for the heating and cooling, as in the case of all the glasses,* without a definite melting or

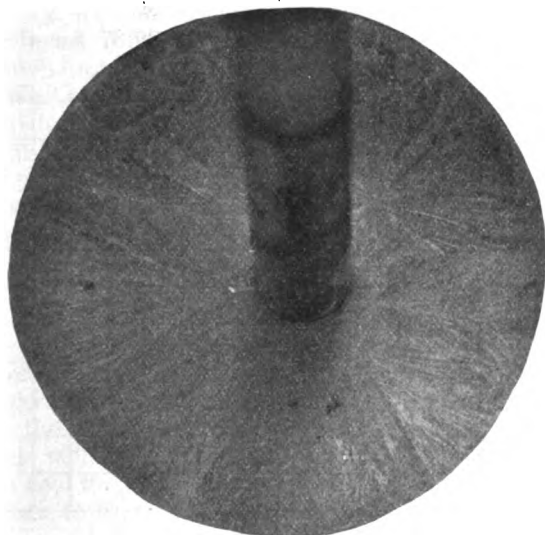


FIG. 2.

solidifying point, although the arrangements for detecting an absorption or release of heat were very sensitive. Prodding at intervals with a platinum rod showed the change to be perfectly gradual from a clear, hard cake through all degrees of viscosity to a fairly thin liquid and back again. This observation is of considerable interest as showing that the absence of bounding phenomena between the cold glass which fulfils the mechanical conditions for a solid very perfectly, and the liquid, is not confined to mixtures of complicated chemical composition, but is exhibited also by true chemical compounds of undoubted purity. It is therefore not conditioned by composition but by the physical nature of the substance. Having verified this behavior of anhydrous borax by several repetitions of the experiment, various disturbing influences were applied to the slowly cooling liquid in the hope that some temperature

* See Tammann, loc. cit., also Roozeboom "Die heterogenen Gleichgewichte, etc." Braunschweig, 1901.

or range of temperature would be found within which the vitreous condition would prove unstable and crystallization be precipitated. The jar produced by an electric hammer pounding upon the outside of the furnace during cooling proved to be sufficient to bring down the entire charge as a beautiful crystalline mass of radial, fibrous structure, brilliant luster, rather high refractive index and increased volume. The photograph (fig. 2) will give some idea of the appearance of the anhydrous crystalline borax in the crucible. Its specific gravity proved to be 2.28 as compared with 2.37 for the glass, a

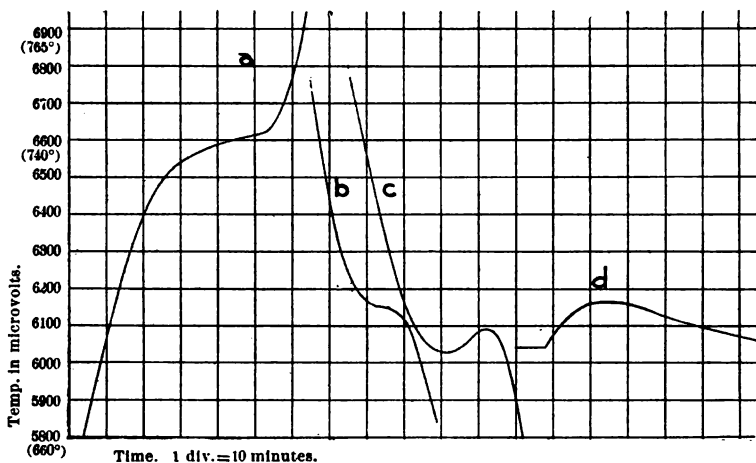


FIG. 3.

somewhat unusual relation,* which may in part account for the quasi-stability of the vitreous form during cooling.

Observations were then undertaken upon the crystalline borax with a thermoelement as before, to determine the melting temperature and solid modifications if such existed, but none of the latter were found. The charge melted uniformly at 742° and the melting point was well defined. A curve showing the minute-to-minute observations on the crystalline borax between the temperatures 660° and 765° is shown in the adjoining figure (fig. 3, *a*).

Having determined the melting point of crystalline anhydrous borax satisfactorily, we examined more closely into the conditions under which it solidified. As has been said, if the melted charge was allowed to cool slowly, undisturbed, no return to the crystalline state occurred. It merely thickened into a transparent glass without releasing the "latent" heat which it

* Tammann. Loc. cit., p. 47 et seq.

had taken on in melting (fig. 5, *b*). If it was subjected to the jarring produced by the electric hammer on the furnace wall, it cooled down a few degrees below the melting point and then began to crystallize, the heat of fusion was set free and a rise in temperature or hump immediately appeared upon the cooling curve as shown in the figure (fig. 3, *b*, *c*, *d*). Up to this point the phenomenon differs but little from the usual behavior of liquids which undercool in solidifying. We then varied the experiment by first cooling quietly to about 100° below the melting point and then introducing a few crystal fragments or starting the pounding. Crystallization and release of the latent heat followed at once. In fact over a range of some 250° immediately below the melting point it proved to be within our power to precipitate the crystallization of the undercooled mass entirely at will. It was even possible to cool the melted charge quietly down to the temperature of the room and remove it from the furnace as a clear glass, then, on a subsequent day, to reheat to some point in this sensitive zone and pound judiciously, when crystallization would at once begin, marked by the release of the latent heat of the previous fusion as before (fig. 4, *a* and *b*). The accompanying curves show the situation clearly. Curves *aa'* and *bb'* (fig. 5), were obtained from charges of crystalline and vitreous borax, respectively, of exactly equal weight, which were cooled and reheated in the same electric furnace under like conditions. The radiation from the furnace for like temperature conditions will also be practically the same, so that the more rapid rate of cooling and of reheating in the crystalline charge indicates a much smaller specific heat than for the vitreous form.

From the point of view of the usual definition of the solidifying point of a substance, a difficulty confronts us here: (1)

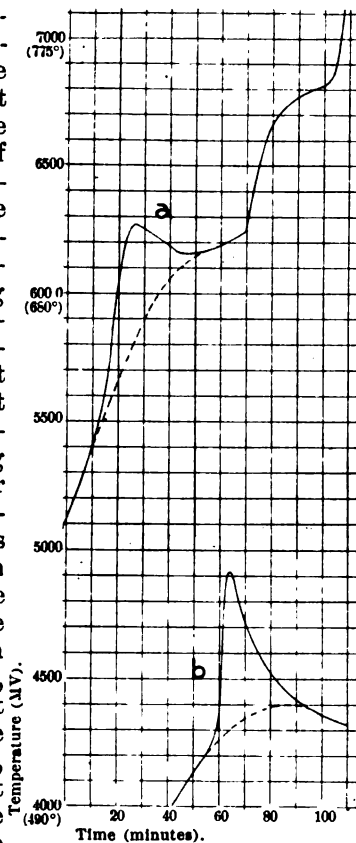


FIG. 4.

we were able to vary the beginning of solidification (crystallization) at will over a range of 250° , and (2) the temperature to which the charge rose after the undercooled liquid had begun to crystallize did not reach the melting point although once

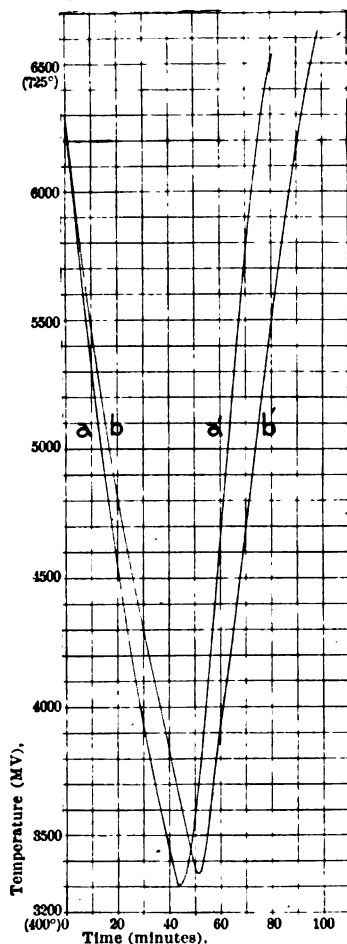


FIG. 5.

general, entitled to be regarded as a physical constant.

We then endeavored to ascertain whether the unstable domain had a lower limit also. For this purpose we mixed a quantity of the crystals with the glass and powdered them together to about the fineness represented by a 150-mesh sieve and heated them very slowly. In this condition the glass proved to be very unstable and crystallized readily with a rapid release of its latent heat at about 490° . Very slow heat-

crystallization was induced only 10° below it in a furnace of constant temperature. The rapidity with which the crystallization and the accompanying release of the latent heat go on, depends in part upon the rate of cooling and the character of the disturbance which has been applied, i. e., upon accidental rather than characteristic conditions. It thus happens that the amount of the heat of fusion and its slow rate of liberation in the case of liquids which can be greatly undercooled and become very viscous, may be such as to deprive it of its usual significance as defining a solidifying point. It is, of course, a consequence of the phase rule that the solidifying temperature of an undercooled liquid is established, if only equilibrium between solid and liquid (and vapor) is reached before complete solidification is accomplished, but equilibrium is *not necessarily attained* during solidification, and the devices usually employed (sowing with crystals, agitating) are often totally inadequate to bring it about. The temperature to which a crystallizing liquid rises after undercooling is not necessarily constant or in any way related to the melting point, and is therefore not, in

ing (10 min. per 1°) gave a temperature a few degrees lower, but such variations as could be applied within the period of a working day did not suffice, under the most favorable conditions, to change this temperature materially. The first evidence of molecular mobility in borax glass, shown in the sticking together of the finest particles (sintering), and the first traces of crystallization and release of latent heat, appeared consistently at about 490–500°. Still a third phenomenon attracted our attention to this temperature. On every occasion when borax glass was heated rapidly, either powdered or in the solid block, a slight but persistent absorption of heat appeared in this same region and continued over some 20°, after which the original rate of heating returned. We were entirely unable to explain an *absorption* of heat in an amorphous substance under these conditions except by assuming an actual change of state to exist between amorphous glass and its melt, in which case the absorbed heat would reappear somewhere upon the corresponding cooling curve,—which it failed to do. We then reasoned that any assumed change in the molecular structure which would account for an absorption of heat would also be likely to cause an interruption in the continuity of the curve of electrical conductivity, and the relative conductivity was determined throughout this region; but no such interruption appeared.

Finally the matter was abandoned. The evidence did not appear sufficient to establish any discontinuity in the cooling curve of the glass, so long as no crystallization took place.

When these relations had been clearly established, we turned again to the feldspars.

It became clear very early in the investigation that only artificially prepared and chemically pure specimens would be adequate for our purpose. Each of the end members of the series, anorthite and albite, as found in nature, is always intermixed with some quantity of the other, while the intermediate members generally contain iron and potash, and all are liable to inclusions.

There was nothing new in this plan: Fouqué and Lévy* had demonstrated the possibility of making pure feldspars by chemical synthesis and had studied their optical properties some years ago. We undertook to prepare much larger quantities than they (200 grams), and to make a careful study of their heating and cooling curves under atmospheric pressure, the conditions under which anorthite and the plagioclases crystallize, the relations between the amorphous and crystalline forms, the sintering of crystalline and vitreous powders, in short, their entire thermal behavior, as we had done with the borax. At the same time it was our purpose to make

* *Synthèse des Minéraux et des Roches*, loc. cit.

careful determinations of the specific gravities of both the vitreous and the crystalline products, analyses of such portions as might be of special interest, and also to prepare microscopic sections wherever they were likely to throw light on the relations involved. The latter, after preliminary examination, were very thoroughly studied by Prof. J. P. Iddings of the University of Chicago, whose large petrographic experience with mineral crystallites makes his judgment of exceptional value.*

The constituents used in our syntheses were precipitated calcium carbonate, anhydrous sodium carbonate, powdered quartz (selected crystals) and alumina prepared by the decomposition of ammonium alum. None of these contained more than traces of impurities, if we except the quartz, in which 0.25 per cent of residue, chiefly oxide of iron, was found after treatment with hydrofluoric and sulphuric acids. All but the calcium carbonate were carefully calcined and cooled in a desiccator before weighing. To obtain a homogeneous product, the weighed constituents were mixed as thoroughly as possible mechanically, and heated in large covered platinum crucibles (100^{cc} capacity) in a Fletcher gas furnace.† After some hours heating, during which the temperature usually reached 1500° or more, the product was removed from the furnace, cracked out of the crucibles, powdered, passed through a "100-mesh" sieve and then melted again. This process probably gives a fairly homogeneous mixture, though a third fusion in the resistance furnace was generally made before determining the constants.

We prepared in this way albite (Ab), anorthite (An) and the following mixtures of the two: Ab,An₂, Ab,An₃, Ab,An₄, Ab,An₅, Ab,An₆, Ab,An₇. All of these were obtained in wholly or partially crystalline form, by crystallization from the melt, except albite. The syntheses were controlled by analyses of a number of the products, the results of which are appended.

ANALYSES OF ARTIFICIAL FELDSPARS.

	An		Ab,An ₂		Ab,An ₃		Ab,An ₄	
	Found.	Calculated.	Found.	Calculated.	Found.	Calculated.	Found.	Calculated.
SiO ₂	43.33	43.28	47.10	47.18	51.06	51.30	60.01	59.81
Al ₂ O ₃	36.21	36.63	34.23	34.00	31.50	31.21	24.95	25.47
Fe ₂ O ₃	.29	----	.15	----	.22	----	.29	----
CaO	20.06	20.09	17.00	16.93	13.65	13.68	7.09	6.98
Na ₂ O	.11	----	1.74	1.87	3.68	3.79	7.79	7.73
	100.00		100.22		100.11		100.13	

* See Pt. II of the complete paper, Publications of the Carnegie Institution of Washington.

† Buffalo Dental Company, No. 41A. A Fletcher furnace of this type, with ordinary city gas pressure and a small blast motor, will melt all of the feldspars.

Anorthite.—Of the whole series of feldspars, this member is in many respects the simplest to deal with. It is of relatively low viscosity when melted and crystallizes easily, very rapidly, and always in large, well developed crystals. A 100-gram charge crystallized completely in ten minutes. Sudden chilling gave a beautiful clear glass entirely free from bubbles, somewhat slower cooling usually resulted in a partial crystallization from few nuclei, the crystals being always large. In appearance it resembles the natural mineral in every respect. Its hardness is also equal to that of natural anorthite. Thin sections show good cleavage, and twinning according to the albite law is frequent. The extinction and other microscopic characteristics are as well marked as in natural specimens.

The heating curve of crystalline anorthite is perfectly smooth except for the single break which marks the melting point. No trace of a second crystalline form (Umwandlung) appeared in this or any other of the feldspars within the temperature range of the observations (300°–1600°). Some undercooling always occurs in solidification even if the rate of cooling is slow, but it is less, under like conditions, with anorthite, than with any other member of the series. The heating curve of the glass shows a strong evolution of heat which may occur as low as 700°, when crystallization takes place. The melting point of crystalline anorthite was determined by three different thermoelements upon two different mineral preparations. It will be seen from the appended table that the determinations agree remarkably well.

ANORTHITE.

First Preparation.

Date.	Element.	M. F.	Tem- perature.	Remarks.
Oct. 7, 1903	A	15939	1534°	solid charge, open crucible.
" " "	A	15914	1532	" "
" 10 "	A	15878	1530	covered crucible.
" " "	No. 3	16074	1533	" "
" " "	3	16058	1532	" "
" " "	3	16068	1532	" "
" " "	2	16095	1532	" "

Mean 1532°

Second Preparation.

Jan. 16, 1904	A	15860	1532°	covered crucible.
" " "	A	15864	1532	
" 20 "	No. 3	15960	1533	
" " "	2	16102	1532	
" " "	2	16092	1532	
Mch. 31 "	3	15932	1531	1st & 2d preparations together.

Mean 1532°

Melting temperature 1532°.

The close agreement of these determinations is of very considerable significance with reference to the method of temperature measurement employed. It will be remembered that the established temperature scale ends at 1150° and that temperatures beyond that point are extrapolated with the help of some trustworthy phenomenon which varies with the temperature. We chose for this purpose the thermoelectric force developed between pure platinum and platinum alloyed with 10 per cent of rhodium. Now the constants of such thermoelements will usually differ among themselves and require to be determined for each element by calibration with the gas thermometer or with the melting points of the metals.* It therefore offers an excellent test of the value of the extrapolation if some sharp melting point can be found in the extrapolated range to serve as a point of reference. The melting point of crystalline anorthite serves this purpose exceedingly well, and separate determinations of it with three separate thermoelectric systems gave identical values within the limits of error of observation. Our confidence that the extrapolation for these 375° is reasonably correct would therefore appear to be justified. Until the gas scale can be extended over this range, the melting point of pure anorthite (1532°) determined in this way will serve as a useful point in thermometry.

Ab. An.—This feldspar decidedly resembles anorthite in its relatively low viscosity, the readiness with which it crystallizes, the well marked break in the heating curve at the melting point, and in its tendency to form comparatively large crystals. In general we may say that all these characteristics are somewhat less marked than in anorthite. Our determinations of the melting temperature follow:

AB ₁ AN ₃					
First Preparation.					
Date.	Element.	Electromotive Force in MV.	Temper- ature.	Remarks.	
Dec. 9, 1903	A	15501	1504°	slow heating.	
" 11, "	A	15363	1493	rapid "	
" 11, "	No. 3	15507	1498	" "	
" 12, "	3	15599	1505	" "	
" " "	3	15594	1505	" "	
" " "	3	15604	1506	slow "	
" " "	A	15518	1505	" "	

Mean 1502°

Second Preparation.					
Apr. 9, 1904	No. 3	15520	1499	slow heating.	
" " "	2	15637	1497	" "	

Mean 1498° .

Melting temperature 1500° .

* Day and Allen, loc. cit.

In one instance, while cooling the molten mass at a rapid rate, we obtained a result which has a most important bearing on the relation of the feldspars to one another, which will be referred to again in the concluding discussion of the experimental data. When the charge had cooled, it was found to consist of a compact mass of rather large crystals, radial in structure, at the bottom of the crucible (fig. 6), and a beautiful, transparent glass above. It was easy to separate the crystalline portion from the glass and to analyze the two separately. The composition of the two portions is practically identical, save for a slightly higher percentage of iron in the crystals.* In harmony with this latter circumstance the color of the crystals was a decided amethyst brown, while the glass was but slightly tinted. The analyses follow:

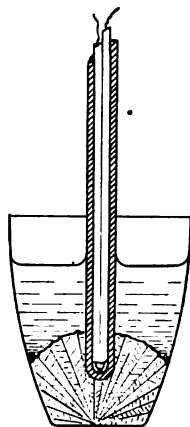


FIG. 6.

AB_1AN_6

	Glass Residue Found.	Crystalline Cake Found.
SiO_2	47.46	47.34
Al_2O_3	33.56	33.51
Fe_2O_3 .....	.29	.47
CaO	16.99	16.84
Na_2O	1.87	1.89
	<hr/> 100.17	<hr/> 100.05

It is at once clear from these determinations that the solid phase has the same composition as the liquid phase, so far as it is within the power of chemical analysis to establish it.

Ab_1An_2 .—In this feldspar we observe the same characteristics as in the two preceding, but they are still less sharply marked. The viscosity is greater, both solidification and melting take place more slowly, and the undercooling is so persistent that the furnace must be cooled slowly or the charge will come out wholly or partly vitreous.

* A small quantity of iron was contained in the quartz used in preparing the feldspars.

AB ₁ AN ₂ .					
First Preparation.					
Date.	Element.	E. M. F. in MV.	Temper- ature.	Remarks.	
Oct. 16, 1903	A	14895	1459°	rapid heating.	
" " "	No. 3	15142	1460	slow "	
" 21 "	3	15101	1457	rapid "	
" " "	3	15220	1466	extremely slow heating.	
" 22 "	3	15204	1465	rapid heating.	
" " "	3	15160	1462		
Dec. 15 "	3	15116	1467	powdered charge, open crucible.	
" " "	3	15103	1466	ditto, slower.	
" 16 "	3	15109	1467	solid cake, covered.	
" " "	3	15044	1462	very fast.	
" " "	3	15040	1462	same slower.	
" " "	A	15035	1467		
<hr/>					
Mean 1463°					
Second Preparation.					
Feb. 19, 1904	A	14945	1460°	covered, slow.	
" 20 "	No. 3	15096	1466	ditto, faster.	
" 25 "	2	15239	1467	fast.	
<hr/>					
Mean 1464°					
Melting temperature 1463°.					

Here again we made an attempt to discover a possible difference in composition in the first portions to crystallize out of the melt, this time by optical means. We first cooled the charge so rapidly that only a relatively small portion crystallized out in fine, reddish-brown spherulites at the surface and near the wall of the crucible. Without disturbing these, the crucible was then replaced in the furnace and slowly reheated until (about 5 hours) the remaining vitreous material had also become completely crystallized. Upon removing from the furnace, the charge presented a singular appearance. The reddish-brown stars remained undisturbed, while the later crystals were perfectly white. But though so different in appearance, the microscopic examination of slides cut from the different portions showed the two to be optically identical.

We have here another instance of the tendency of the iron to concentrate in the crystals which first form, a tendency which was frequently noticed throughout our work. It also appeared to matter little whether the first crystals formed at the surface or at the bottom of the charge. It is possible that this phenomenon may have significance in ore deposition, but we have not thus far been able to give it adequate attention.

Ab, An.—With this member of the feldspar group a difficulty in effecting crystallization in the molten mass becomes noticeable. Undercooling will continue until the vitreous melt becomes rigid, unless the cooling is slow or some special effort in the way of mechanical disturbance or the introduction of nuclei is applied. Furthermore, when once precipitated, crystal formation goes on slowly, even when the charge is finely powdered, and the crystals are always small. Of the feldspars at least it is possible to say that the size of individual crystals varied chiefly with the viscosity; the thinner, calcic feldspars always gave large individuals, while *Ab, An.*, *Ab, An.*, *Ab, An.*, and *Ab, An.* crystallized in closely interwoven, increasingly smaller fibers, which gave much difficulty in microscopic study. In comparison with this apparent effect of the viscosity, the rate of cooling was altogether insignificant in determining the size of individual crystals.

Several days were required to complete the crystallization of 100 grams of *Ab, An.* under the most favorable conditions which we were able to bring to bear upon it. The melting temperature of the crystalline feldspar was still fairly well marked, however, and crystallization began in the powdered vitreous material as low as 700°. The melting point of this feldspar is:

		<i>AB, AN.</i>		Remarks.
Date.	Element.	E. M. F. in MV.	Temperature.	
Feb. 9, 1904	A	14402	1416°	covered charge, heating rapid.
" 9,	" A	14400	1416	
" 10,	" No. 3	14529	1421	very rapid.
" 12,	" 2	14572	1415	
" 27,	" 2	14709	1426	very small charge.

Mean 1419°

Melting temperature 1419°.

Ab, An.—To effect the complete crystallization of this substance, it is best to reduce it to a fine powder and heat very slowly, holding the temperature for many days at 100–200° below the melting point. When thoroughly crystallized, it has a melting temperature which is determinable with reasonable certainty, but neither this nor any of its thermal phenomena approach the more calcic feldspars in sharpness. For this reason a considerably greater variation will be noticed in the melting points tabulated below.

AB_1AN_1 .					
First Preparation.					
Date.	Element.	E. M. F. in MV.	Tem- perature.	Remarks.	
Dec. 10, 1903	A	13726	1362°		
" 15, "	A	13887	1374		
" 16, "	A	13969	1381	very rapid heating.	
" 16, "	A	13728	1362	poor.	
Jan. 18, 1904	No. 3	13967	1376	covered.	
Feb. 29, "	3	13812	1363	"	
" 29, "	3	13854	1366	"	

Mean 1369°

Second Preparation.					
Feb. 5, 1904	No. 2	13990	1369°	covered.	

Third Preparation.					
Mch. 25, 1904	3	13752	1358		
" 29, "	2	13995	1370		
Apr. 5, "	3	13756	1358		

Mean 1362°

Melting temperature 1367°.

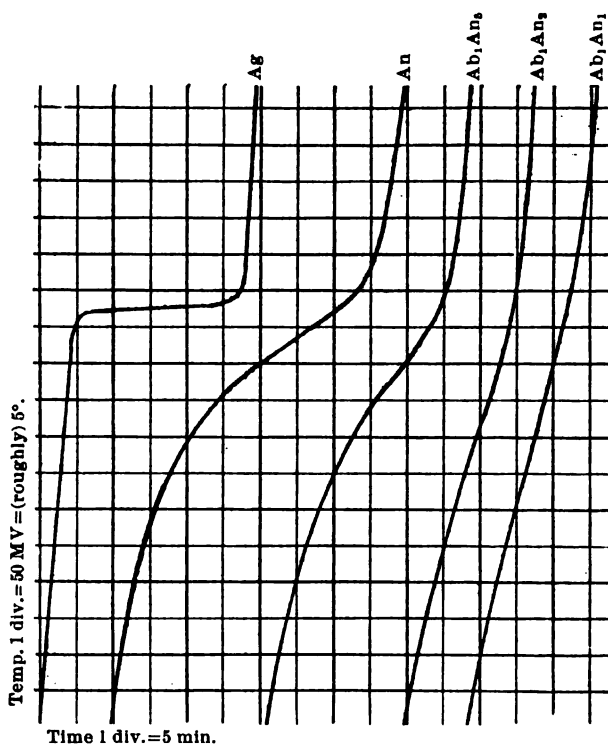


FIG. 7.

From here on to the albite end of the series, viscosity becomes very troublesome in restraining crystallization. The breaks which mark the melting temperature on the heating curve of Ab, An, are so slight as to make the determination difficult and somewhat uncertain. It is not that temperature measurement is less accurate here than elsewhere, for these temperatures are more accessible than the melting point of anorthite, to which reference has been made in this connection. These ultra-viscous materials do not melt at a constant temperature but over a considerable range of temperature, as we shall undertake to show in some detail, with illustrations from photographs, in the discussion of albite. A glance at a series of curves (fig. 7) plotted from our observations upon metallic silver and the feldspars An, Ab, An, Ab, An, and Ab, An, in such a way as to bring their melting points together, will show clearly the nature of this difficulty. The melting point of the metal is sharp, but with anorthite a change in the character of the phenomenon is noticeable. Its poor conductivity for heat and its viscosity, which, though small compared with the other feldspars, is very great compared with silver, have rounded off the corners until a really constant temperature for a period of a minute or more during the melting is nowhere to be found. The nearest approach to a melting point is where the rise in temperature is slowest, and this will occur when the portion nearest to the thermoelement (see fig. 1) melts. A series of melting point curves containing a typical one for each of the observed feldspars, is reproduced here exactly as observed (see page 114). The numbers represent the electromotive force of the thermoelements at intervals of one minute, together with a column of differences at the right of each record. The E.M.F. will be seen to approach a minimum as melting progresses and to increase again when it is complete. This minimum rise in the temperature of course indicates the maximum absorption of heat. For purposes of rough orientation 10 MV may be considered equivalent to one degree.

There is no circulation in these viscous melts and nothing to assist in distributing the heat uniformly. The melting point is therefore not marked by a constant temperature but by the point of greatest inclination of the tangent to the curve, with a limit of error which increases with increasing viscosity. With Ab, An, it was barely discernible and with Ab, An, all trace of the heat of fusion was lost.* Slow heating or rapid

* Only a small portion of the charge could be crystallized. The relatively small heat of fusion of the crystallized portion was therefore superposed upon the larger specific heat of the glass. This, together with the effect of the viscosity, destroyed all record of the melting.

TIME CURVES

(in Microvolts as observed).

An		Ab, An ₁		Ab ₁ An ₂		Ab ₁ An ₁		Ab ₂ An ₁		Ab ₂ An ₁	
MV	ΔV	MV	ΔV	MV	ΔV	MV	ΔV	MV	ΔV	MV	ΔV
15050	156	13530	300	11700	510	13400	89	12480	53	12754	39
15206	135	13830	300	12210	445	13489	84	12533	57	12793	41
15341	100	14130	240	12655	305	13573	74	12590	58	12834	43
15441	85	14370	190	12960	276	13647	68	12648	53	12877	39
15526	68	14560	153	13236	205	13715	63	12701	51	12916	38
15594	56	14713	125	13441	154	13778	58	12752	45	12954	35
15650	47	14838	104	13595	127	13836	55	12797	43	12989	33
15697	41	14942	86	13722	110	13891	51	12840	41	13022	31
15738	35	15028	73	13832	100	13942	49	12881	36	13053	29
15773	29	15101	63	13932	90	13991	47	12917	35	13082	27
15802	27	15164	54	14022	85	14038	45	12952	35	13109	25
15829	24	15218	46	14107	79	14083	42	12987	33	13134	26
15853	22	15264	39	14186	70	14125	41	13020	33	13160	24
15875	16	15303	36	14256	67	14166	40	13053	35	13184	23
15891	15	15339	32	14323	70	14206	39	13088	33	13207	22
15906	14	15371	27	14393	63	14245	39	13121	33	13229	21
15920	13	15398	25	14456	58	14284	39	13154	30	13250	20
15933	12	15423	24	14514	57	14323	40	13184	31	13270	18
15945	11	15447	21	14571	49	14363	39	13215	33	13288	18
15956	9	15468	20	14620	50	14402	42	13248	35	13306	15
15965	9	15488	16	14670	44	14444	44	13283	35	13321	16
15974	9	15504	17	14714	45	14488	50	13318	37	13337	17
15983	9	15521	16	14759	38	14538	67	13355	33	13354	19
15992	6	15537	15	14797	42	14605	71	13388	33	13373	20
15998	6	15552	15	14839	38	14676		13421	30	13393	22
16004	8	15567	14	14877	35			13451	32	13415	24
16012	8	15581	13	14912	35			13483	33	13439	27
16020	8	15594	14	14947	35			13516	31	13466	27
16028	5	15608	14	14982	31			13547	29	13493	27
16033	7	15622	15	15013	33			13576	26	13520	28
16040	8	15637	17	15046	36			13602	25	13548	28
16048	8	15654	18	15082	36			13627	21	13576	
16056	8	15672	23	15118	42			13648	18		
16064	7	15695	38	15160	51			13664	11		
16071	7	15733	63	15211	95			13675	21		
16078	9	15796		15306	113			13696	28		
16087	12			15419				13724	34		
16099	11							13758	36		
16110	12							13794	39		
16122	12							13833	40		
16134	15							13873	41		
16149	14							13914	40		
16163	18							13954	44		
16181	16							13998	52		
16197	16							14050			
16213	19										
16232											

heating merely acts to change the general inclination of the curve but not to emphasize the absorption of heat.

By way of conveying a concrete impression, it may be added that Ab_4An_1 , just above its melting temperature resists the introduction of a stout platinum wire (1.5^{mm} diameter) unless the cold wire is thrust in very quickly and vigorously. If the wire is first allowed to become hot in the furnace, it will give way itself instead. No acceleration of the melting process tending to sharpen the break in the curve appears to be possible without the introduction of new substances or new conditions (water vapor under pressure for example) which would take the experiment outside the definition of a "dry melt." We have undertaken some preliminary experiments in these directions, but they belong to another phase of the subject.

A number of efforts were made to locate the melting temperature of Ab_4An_1 , which are given in the list below. Although two days were required to crystallize each charge of the material sufficiently for a determination, the recorded numbers possess but little significance, as will be clear from the foregoing.

AB ₂ AN ₁				
First Preparation.				
Date.	Element.	Electromotive Force in MV.	Temperature.	Remarks.
Nov. 23, 1903	A	-----	1325°	
" 25, "	A	13415	1336	
" 28, "	A	13698	1359	
Dec. 26, "	A	13319	1328	
Jan. 14, 1904	No. 3	13893	1370	
			Mean 1344°	
Second Preparation.				
Mch. 11, 1904	A	13218	1320	
" 14, "	No. 3	13469	1335	
			1329°	
Approximate melting temperature 1340°.				

Ab_4An_1 .—With Ab_4An_1 , a third proof of the identity of composition of the first crystals to separate and the vitreous residue was obtained. The optical identification of this feldspar is absolute. If we could obtain crystals at all in a melt of this chemical composition, therefore, it would offer a crucial test of the relation of the solid and liquid phases in a part of the curve where no melting point or specific gravity determination upon crystals was possible. After some days of nearly continuous heating at a temperature somewhat below its assumed melting point, a few crystals of Ab_4An_1 were obtained and identified.

Albite.—From the experiments upon natural albite and orthoclase, which have been described, and after observing the effect of the increasing viscosity as we approached the albite end of the artificial plagioclase series, we had no expectation of finding a melting point for either in the ordinary sense. Nor did we in fact succeed in locating a point of any real significance in this connection. The various trials which were made were simply calculated to throw all the light possible upon the character of the change from (crystalline) solid to liquid in such extremely viscous substances. The return change or recrystallization of such substances from the melt (solidifying point) without the introduction of modifying conditions has never been accomplished. The time required to do it is certainly very great, probably much greater than the demonstration is worth at the present stage of experimentation in this field.

Crystalline albite has been produced under exceptional conditions several times—by Hautefeuille,* by heating a very alkaline aluminosilicate with sodium tungstate for 30 days at 900°-1000°; by Friedel and Sarasin,† using an atmosphere of water-vapor under high pressure and a moderately high temperature (an aqueo-igneous fusion); by J. Lenarčič,‡ at ordinary pressure and high temperature by crystallization out of a mixture of melted albite and magnetite (1 part magnetite, 2 parts albite by weight), and by others. It may be noted in passing that, entirely apart from the solution relations, the last mentioned process reduces the viscosity to an entirely different order of magnitude from that of pure albite; magnetite melts to form a thin liquid almost of the consistency of water and even in 1:10 solution with albite forms a fairly mobile liquid. We endeavored to repeat portions of the work of Hautefeuille and Lenarčič, but were obliged to postpone a systematic inquiry into the conditions of crystallization which involved the addition of other components or extraordinary pressures, until our plant could be somewhat extended.

Hautefeuille describes his successful preparation as a “solution” of the alkaline aluminosilicate in sodium tungstate out of which the albite slowly crystallizes after long heating, but he remarks that the crystallization does not take place if the mixture is heated sufficiently to melt the components of the charge into a homogeneous glass. In that case he obtained only a vitreous white enamel. The case does not appear, therefore, to be one of simple solution, out of which the same

* Hautefeuille, *Annales de l'École Normale Supérieure*, 2d series, ix, p. 363, 1880.

† Friedel and Sarasin. *Bull. Min.*, clviii, 1879; lxxi, 1881.

‡ J. Lenarčič, *Centralblatt f. Min.*, xxiii, 705, 1903.

solid phase always reappears upon reproducing given conditions of temperature and concentration. On the contrary, as Hautefeuille describes the experiment, the components of the albite remain as independent solid phases, which are then assembled in some manner through the intermediary action of the melted tungstate.

Notwithstanding the fact that our interest was confined for the moment to the mere production of a small quantity of chemically pure crystalline albite, we ventured to proceed along the lines of Hautefeuille's unsuccessful trial. We first prepared a chemically pure albite glass, i. e., we melted the components into a homogeneous mass before adding tungstate. This glass was then finely powdered, thoroughly mixed with an excess of powdered sodium tungstate and maintained continuously for 8 days at 1100° . Upon removing from the furnace at the close of the heating, both albite and tungstate were found to have been completely melted and to have separated into two distinct layers according to their specific gravities, the albite glass being above, and showing no trace of crystallization. A second charge was then prepared with only 50 per cent of the tungstate, powdered and mechanically mixed as before, and maintained at a temperature of 900° for 17 days. This time we were successful. After the sodium tungstate had been dissolved away with water, the albite appeared as a powder of about the fineness to which it had originally been pulverized, except that the fragments were now crystalline and apparently homogeneous albite. In thin section, under the microscope, to our considerable surprise, it appeared that the original glass fragments were unchanged in form. The bounding surfaces were all conchoidal fractures, as they came from the hammer, and evidently had not been in solution with the tungstate at all. Its optical properties showed it to be undoubted albite and the specific gravity was 2.620.

The preparation of albite which we had synthesized by heating with an equal weight of sodium tungstate was first purified by thorough washing with warm water, but this was not sufficient to remove all the tungstate. A determination of tungstic acid showed 0.62 per cent still present, which is equivalent to 0.78 per cent of sodium tungstate. After removing the water by heating carefully to a dull redness, the product was submitted to a microscopic examination, which showed it to be entirely crystalline and apparently homogeneous. Determinations of the specific gravity gave 2.620 (see table, p. 128). If this is corrected for 0.78 per cent of sodium tungstate of specific gravity 4.2, we obtain 2.607.

A portion of this preparation was then purified further by fusing for a few minutes with acid sodium sulphate (Haute-

feuille) at as low a temperature as practicable, after which the excess of sulphate was extracted with water and the product dried (the temperature was raised to a dull red heat to remove all water) and analyzed.

	Found.	Calculated.
SiO ₂	68.74	68.68
Al ₂ O ₃ and }	19.56	19.49
Fe ₂ O ₃ }		
Na ₂ O	11.73	11.83
SO ₃ .....	.02	
WO ₃ .....	.16	
	<hr/> 100.21	

The specific gravity of it was 2.604, which may be corrected as before for the remaining trace of tungstic acid assumed to be in the form of the sodium salt. The value then falls to 2.601.

A second portion of the same albite was purified by another process. Instead of fusing with acid sodium sulphate, the powdered sample was first digested for a short time with dilute hydrochloric acid (1:1), which set free tungstic acid. The excess of hydrochloric acid was removed with water, the tungstic acid with ammonia, and finally the excess of reagent and the ammonium tungstate by further washing with water. When dried at a low red heat, the preparation had the following composition :

	Found.	Calculated.
SiO ₂	68.91	68.68
Al ₂ O ₃	18.95	19.49
Fe ₂ O ₃ .....	.18	
Na ₂ O	11.59	11.83
WO ₃ .....	.22	
H ₂ O .....	.13	
	<hr/> 99.98	

The specific gravity determination gave 2.615, which when corrected for a small amount of sodium tungstate becomes 2.612. If, as is possible after the above treatment, the tungstic acid is present as the anhydride, sp. gr. 7.1, the correction would lower the value to 2.605, in excellent agreement with the other determinations.

The products of both methods of purification were carefully scrutinized by the microscope, but no conclusion could be reached as to which was the purer. Neither the sodium sul-

phate fusion nor the digestion with acid and ammonia appeared to have changed the particles in the slightest degree. Diligent search was made for opaque or amorphous matter on the surface of the grains, or any other indication of decomposition, but none was found. While the chemical analysis indicates a rather higher purity for the first product, purified by fusion, the differences are nearly within the limits of error and therefore hardly conclusive. Both powders were ground finer than usual for the specific gravity determinations to avoid errors introduced by a spongy structure.

Reverting now to Hantefeuille's directions, it is clear that glass of albite composition crystallizes homogeneously under substantially the conditions which he obtained, as well or better than the mechanically mixed component parts; but the part played by the tungstate requires some further experimental study before a conclusion can be reached.

Except for the specific gravity, the experiments upon crystalline albite and orthoclase which follow were made upon natural specimens from well-known localities (a fragment of the Mitchell Co. albite is shown in Plate I, 1), for which we are indebted to Dr. G. P. Merrill of the National Museum and Dr. Joseph Hyde Pratt, State Mineralogist of North Carolina. The specimens were selected with great care, but like all natural specimens, they contained other feldspars and inclusions. The analyses follow:

	Albite. (Amelia Co., Va., Nat. Mus.)		Albite. (Mitchell Co., N. C., Pratt.)		Microcline. (Mitchell Co., N. C., Nat. Mus.)	
	Found.	Calculated, Anhydrous.	Found.	Calculated, Anhydrous.	Found.	Calculated, Anhydrous.
SiO ₂ ..	68.22	68.71	66.03	66.42	65.49	65.83
Al ₂ O ₃ ..	19.06	19.20	20.91	21.03	17.98	18.07
Fe ₂ O ₃ ..	.15	.15	.18	.18	.36	.36
CaO ..	.40	.40	2.00	2.00	.42	.42
Na ₂ O ..	11.47	11.53	9.97	10.03	2.29	2.30
K ₂ O ..	.20	.20	.70	.70	12.95	13.02
H ₂ O ..	.69	....	.59	....	.51	....
	<hr/> 100.19		<hr/> 100.38		<hr/> 100.00	

It will be remembered that in the preliminary experiments (p. 98) the heating curve of these natural feldspars did not show an absorption of heat which we were able to detect; our first step was therefore to find out what manner of process it was by which a charge of crystalline albite or orthoclase became amorphous without leaving a thermal record behind.

We prepared a charge of albite glass from a previous melt powdered to "100-mesh." In this glass powder a small crystal fragment (perhaps $2 \times 5 \times 10^{mm}$), from the same original speci-

men and therefore of the same chemical composition, was imbedded beside the thermoelement as indicated in fig. 8. This charge was heated slowly to exactly 1200° , slowly cooled again and several thin sections prepared from the crystal fragment and its immediate neighborhood. What the microscope showed can best be seen from the accompanying illustrations (Plate I, 2 et seq.),—groups of crystal fragments of microscopic size, preserving their original orientation (extinction) perfectly but with narrow lanes of glass where cleavage and other cracks had been, forming a perfect network without a trace of disarrangement. Considerable melting had taken place but no flow. Neither had the charge as a whole made any movement to take the form of the containing vessel after sintering together (fig. 9).

Surmising that we had accidentally hit upon the approximate melting temperature, a fresh charge of like material was

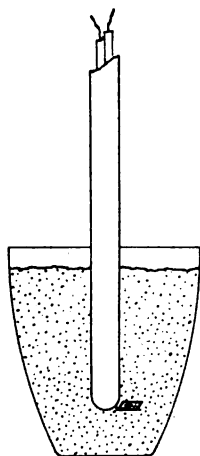


FIG. 8.

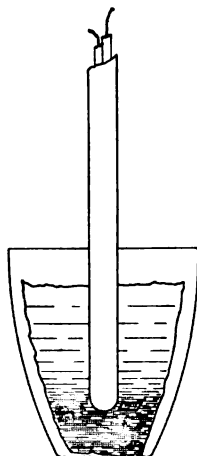
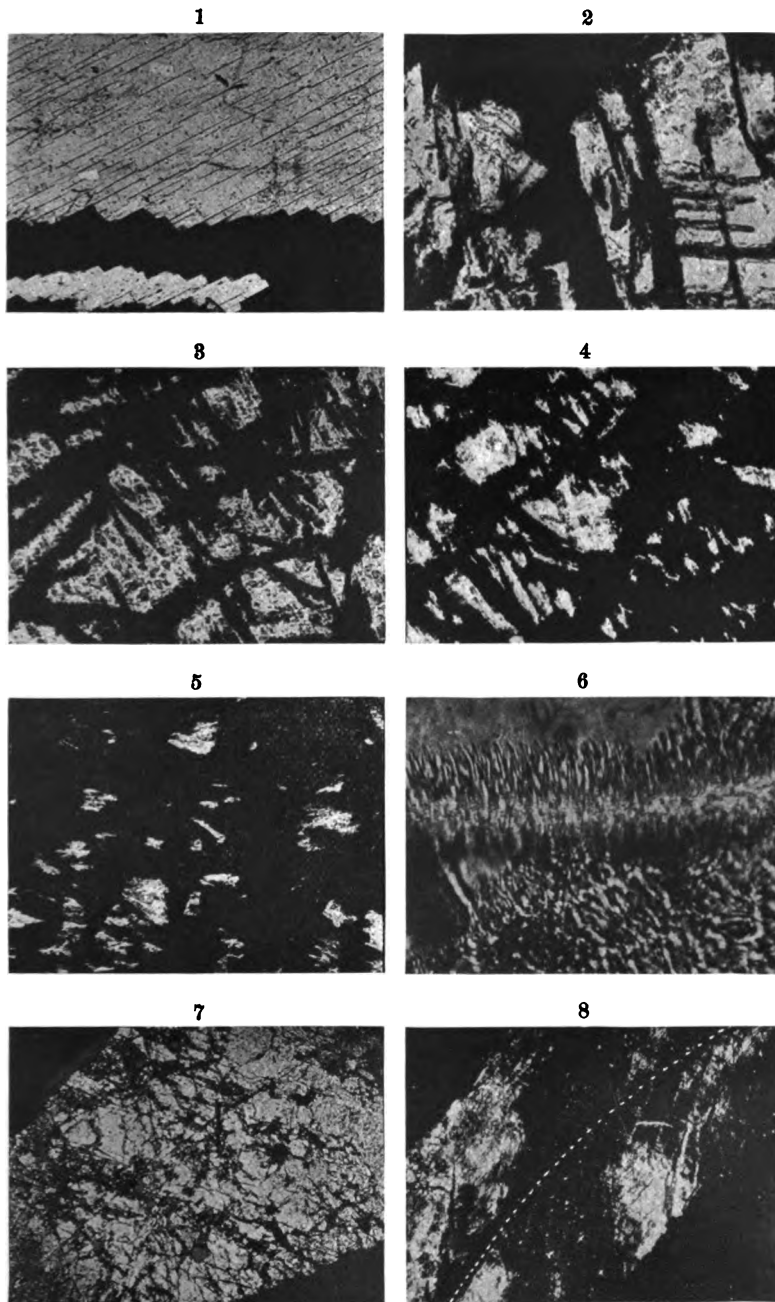


FIG. 9.

prepared, and the same experiment carefully repeated except that the temperature was carried up to 1206° and maintained there for 30 minutes. Instead of showing the melting to be complete, the slides (Plate I, 3) looked precisely like the first save that the lanes of glass were somewhat wider and the crystal fragments relatively smaller than before. Further trials under precisely the same conditions with the temperature increased to 1225° (Plate I, 4) and 1250° (Plate I, 5) respectively, for like periods of time, showed only more advanced stages in the same process. In the latter case the



1. Original Albite (Mitchell Co.), $\times 10$. 2. Fragment of same heated to 1200° , $\times 20$. 3. Another fragment, 1206° , $\times 20$. 4. Another, 1225° , $\times 20$. 5. Another, 1250° , $\times 20$. 6. Another ($\times 800$) four hours at 1125° . 7. Another, bent at 1200° , $\times 10$. 8. Microcline bent at 1200° , $\times 10$; note the direction of cleavage (cf. dotted line). All the photographs were made through crossed nicols, vitreous areas are therefore black.

remaining crystal fragments were relatively very small compared with the separating lanes of glass, but the orientation of the tiny particles still remained perfectly undisturbed.

The evidence contained in this series of slides shows plainly that we have here an unfamiliar condition—a case of a crystalline compound persisting for a long time above its melting temperature for a given pressure. Albite or orthoclase glass sinters tightly at 800°. At the temperature when melting began, therefore (below 1200°), the charge consisted of crystal fragments of microscopic size imbedded in a large vitreous mass of the same composition and known temperature. These fragments melted so slowly over the 50° included between the first slide (Plate I, 2) and the last (Plate I, 5), with the rate of heating slow (1° in 2 min.), and the upper temperature continued for 30 minutes, as to leave considerable portions unmelted at the close. Furthermore the extreme viscosity, of which further evidence will be given directly, and the absence of any disturbance in the orientation of the particles indicating flow, assured us that the lanes of glass represented actual melting and not an inflow of glass from without. Finally, the perfectly homogeneous character of the glass and the unchanged appearance of the crystals as heating progressed, gave no hint of any chemical decomposition.

In the hope of obtaining a point of value for comparison with the melting points of the other feldspars, some time and patience were expended in trying to locate the lowest temperature at which certain evidence of melting appeared. We did not extend any single trial beyond a single day, so that our results can not pretend to establish the lowest point at which albite melts. Such an effort with a natural specimen known to contain impurities would yield nothing of value. Mitchell County albite showed signs of melting after four hours at 1100°. Under a high power the crystal edges appeared weathered or toothed—strongly resembling the incipient melting of the ice on a frosted window pane. These extremely fine teeth could be followed through the slide on exposed edges. At 1125° (Plate I, 6, $\times 300$) a four-hours heating gave unmistakable glass in tiny pockets and lanes.

The above experiments with the Cloudland albite were completed before we obtained the Amelia County material, but the latter proved to be so much nearer to the type of pure soda feldspar that nearly all the experiments were repeated with it except that the crystal blocks were imbedded in powdered crystals. We did not develop any new fact, however; the effects noted above reappeared in the same order except perhaps that melting went on a little faster in the Amelia County specimen. As much melting was found after one-half hour at

1200° with the Amelia County sample as the Cloudland (Mitchell County) showed in the same time at 1225°, which is readily enough explained by the relatively large quantity of lime (anorthite) in the latter.

Since both time and temperature enter into the delimitation of the metastable region, further trials at temperatures above 1250° did not seem likely to add anything to the knowledge already obtained. And if the heating were very rapid, the temperature differences within the charge would be considerable. A few isolated crystalline fragments were found in an orthoclase melt which had been heated as high as 1400° for another purpose. Another which had reached nearly 1500° showed no orthoclase, but one or two minute quartz inclusions still remained undissolved.

We made a rough attempt to get a more tangible idea of the viscosity of these feldspars at their melting temperature in the following way. A long, slender sliver (perhaps 30x2x1^{mm}) of albite and one of microcline were chipped from larger portions, spanned across small empty platinum crucibles, and placed side by side in the furnace. These exposed crystals were heated to 1225° for three hours. When removed, they were completely amorphous (melted) but retained their position with hardly a trace of sagging.

After this a number of similar slivers were prepared, mounted in the same way, and heated to temperatures of from 1200° to 1300° for a few moments. At their highest temperature a platinum rod was inserted through a hole in the top of the furnace and allowed to rest as a load upon the middle of the crystal bridges. Under this load the partially melted slivers gradually gave way, and were taken from the furnace in the various forms shown in the illustrations. Slides cut from these showed no squeezing out of the melted portion between the crystal fragments on the side toward the center of curvature, or open cracks on the outer side (Plate I, 7, 8.) On the other hand, a variable extinction angle in an unbroken crystal fragment frequently gave unmistakable evidence of the bending of the crystal as well as the vitreous portion. From these qualitative experiments it seems possible to assert with confidence that the order of magnitude of the viscosity of the molten portion (glass) is the same as the rigidity of the crystals at these temperatures.

Plate I, 7, shows a piece of Mitchell Co. albite heated to 1200° under load. The sagging is indicated by the curved cleavage cracks. Plate I, 8, shows a sliver of microcline which has been heated to 1200° under load. The sagging is shown by the curvature of the crystal edges and the cleavage cracks.

The black portions are glass. It is interesting to observe that while the crystal has melted completely across, there has been no displacement of the cleavage plane.

The preceding experiments gave a clear idea of the phenomena attending the melting of albite and orthoclase, and convinced us that the absorption of heat accompanying fusion, which we had searched for in vain upon the heating curves in the earlier experiments, had eluded us merely because it was extended over so long a stretch of the curve as not to be noticeable. Some very exact measurements of the temperature change from minute to minute were therefore made in the hope that a more intelligent search might be more successful. Separate charges of glass and of crystals of the same composition and of equal weight were prepared and successively heated in the same furnace with the same current. The specific heat is of course not identical in the two

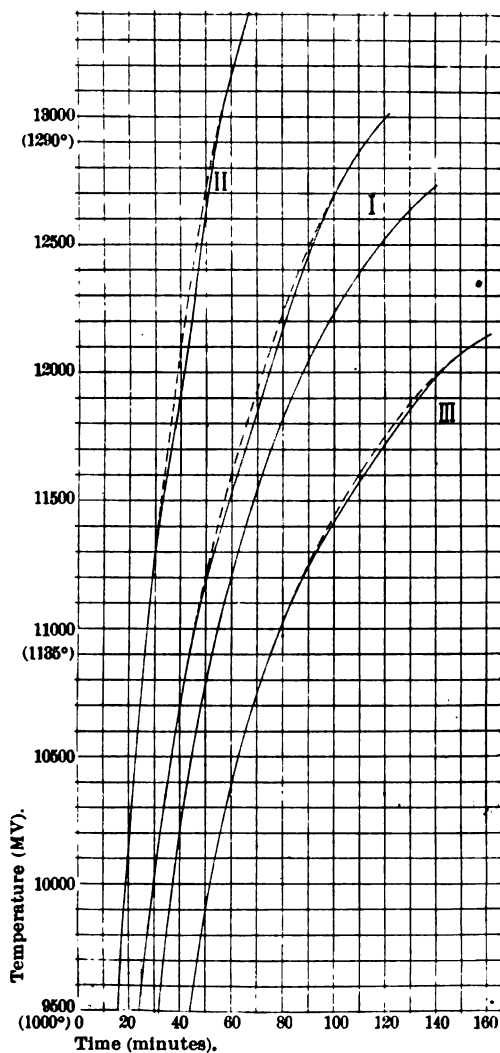


FIG. 10.

cases, but the curves were comparable in form. Above 1100° we felt sure that one of the curves must contain an absorption of heat which would be absent from the other. Such

a pair of curves, I, taken from the microcline measurements, is reproduced in the adjoining figure (fig. 10), and appears to show such an absorption clearly, extending from 1135° to 1275° . The dotted line shows the course of the curve without the absorption, as inferred from the glass curve. The same figure contains two other curves (II, III), similarly treated, which were made upon fresh charges of the same material, but with different rates of heating. It will be noticed that the absorption begins to be noticeable at a slightly lower temperature if the heating is slower.

This peculiar behavior shown by compounds which melt to form hyperviscous liquids seems not to have been observed before and to contain features of more than ordinary interest. Here are evidently crystalline substances which not only can exist for considerable periods of time at temperatures far above their melting temperatures, but which melt with extreme slowness in the lower portion of this range of instability. It would certainly be no exaggeration to say that the albite with which we worked would require some weeks to reach the amorphous state if maintained at a constant temperature of 1125° .

An interesting question arises here as to the state of the crystalline material at temperatures above its melting point. It is easily conceivable that the crystals are merely superheated without loss of any of their properties as solids, and that they thus present an analogy to superheated liquids. In the transformation (*Umwandlung*) of a solid crystalline substance into another crystal form, such superheating has long been known. The change is dependent upon temperature and pressure like ordinary fusion, but it is possible to pass the transformation temperature in either direction. This must be due to the unfavorable opportunity for molecular motion which solids afford, and the latter should differ in no essential particular from ultraviscosity.

On the other hand, it does not seem a violation of any known principle to conceive cases of unstable equilibrium in which the molecules of a liquid are oriented as in a crystal. Maxwell's demons might arrange them much like a school of fish and there is no apparent reason why the fluidity should be destroyed thereby. Were such an arrangement one of minimum potential, the mass would be a liquid crystal. In the supposed case such a substance would possess a melting point dependent upon the temperature and pressure, above which Maxwell's definition* of a true solid—that its viscosity be infinite—would no longer obtain, although deorientation might not become apparent, in the face of extreme viscosity, for a

* Maxwell's Scientific Papers, vol. ii, p. 620.

considerable time afterward. Such a melting point would be determinable only with the greatest difficulty, for all the functions—mechanical, thermal or electrical—which usually become suddenly discontinuous at the melting point would be equally powerless to define a change of state in the face of such extreme molecular inertia.

In substances like these, which are still viscous at the temperature of the electric arc, the sharpness of a minimum due to heat absorption, for example, is not dependent upon the magnitude of that absorption entirely, but also upon the rapidity with which the change which involves it proceeds. In albite and orthoclase, the velocity of this change is very small.

Specific Gravity.—The study of the specific gravities yielded one interesting result which was not anticipated. The artificial feldspars, being chemically pure and homogeneous, gave a perfectly definite specific gravity which could be determined with great accuracy if the specimen was completely crystallized. If vitreous inclusions were still present, the results were of course variable and were all too low. It was anticipated that the density of pure glasses, transparent and free from bubbles, as they were in the more calcic members of the series, might yield values varying more or less with the rate of cooling, or after annealing, but this did not prove to be the case. Our results did not vary more than two units in the third decimal place in the same preparation even with the more calcic feldspars which required to be very rapidly chilled in order to cool the melt without crystallization.

The determination of specific gravities is a trite subject, but we have found the common methods liable to such grave errors that we venture to give some useful details. The error due to the evaporation of water about the stopper of the pycnometer is very much less with finely ground stoppers than with coarse grinding, and if the stopper is slightly vaselined just before the final weighing, the error from this cause will hardly affect the third decimal place with 25^{cc} pycnometers. The simplest form of flask with a small capillary opening in the stopper, is, in our judgment, far superior to one carrying a thermometer. The temperature should be made sure by the use of the thermostat.

For removing the air from a powdered charge, we used the device of G. E. Moore,* slightly modified, as indicated in the accompanying sketch. The bulb *A* contains boiled water.

*G. E. Moore, Jour. prakt. Chem., ii, p. 319, 1870.

When the apparatus is exhausted, the water is allowed to flow back into the pycnometer containing the charge; then by tapping and warming with water at 40–50° to produce boiling within, the air is effectively removed. The material projected from the flask, if the boiling is violent, is then washed back from the tube *B* with boiled water and any small particles remaining are washed into a tared dish and finally weighed. It is very important that not the smallest grain of material should get into the ground joint between the neck and stopper of the pycnometer. To obviate this, wipe out the neck with filter paper before stoppering and burn it in the tared dish.

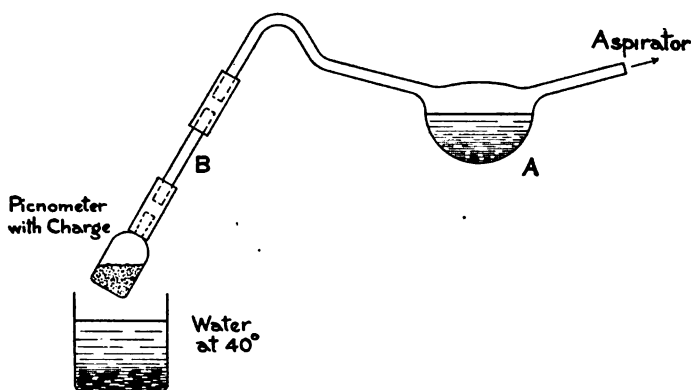


FIG. 11.

If the powder is very fine it is advisable to allow the filled pycnometer to stand for some hours in the thermostat, in order that suspended material may settle. With a 25° pycnometer and 5 to 10 grams of material, this method usually yields concordant results to the third decimal place, and the error from all causes should never be greater than two units (± 1) in the third place. A determination of this accuracy is of course subject to a correction for buoyancy, and all the numbers which follow have been thus corrected.

There is another error to which accurate specific gravity determinations upon powdered minerals will be subject unless suitable precaution is taken. The exposure to the air during the period of grinding the samples gives opportunity for the condensation of sufficient atmospheric moisture upon the grains to affect the weight in air. The amount varies measurably with the size of the grains, as will be seen from the accompanying data, and probably with the degree of saturation of the atmosphere and the time of exposure.

DETERMINATION OF MOISTURE IN 1 GR. OF POWDERED MINERAL UPON
EXPOSURE TO THE AIR.

Mineral.	Fineness (mesh).	Moisture.
Orthoclase (natural glass)	< 150	·0061 gr.
Ab, An, (artificial glass)	selected, coarse	·0000
" (" cryst.)	< 100 > 120	·0010
Ab, An, (" glass)	< 100 > 120	·0007
" (" cryst.)	< 100 > 120	·0010
Ab (natural ")	coarse	·0006
Ab (" ")	< 150	·0069
Orthoclase (natural cryst.)	< 120 > 150	·0011 gr.
" (same sample)	< 150	·0031
" (" ")	still finer	·0059
Orthoclase (artificial glass)	everything < 100	·0065 gr.
" (portion of same)	> 150	·0022
	< = finer than	> = coarser than

In the last two groups, note that the moisture in selected portions of the same sample varies with the fineness.

We also verified the conclusion of Bunsen* that this adsorbed moisture is not removed at temperatures only slightly above 100° but requires 600° to 800°—equivalent to a low red heat. Several samples for which the moisture had been determined were laid away in corked test tubes for a number of weeks, after which redetermination gave exactly the former value.

It is worth noting in this connection that these measured quantities of adsorbed water are of the same order of magnitude as those usually obtained for the water content in feldspar analyses,† where again, of course, the finer the sample is ground for the analysis, the greater the possible error from this cause. It may be that a part and occasionally all of the moisture usually found in these analyses is adsorbed and the significance of its presence there mistaken.

The number of feldspars of which specific gravity determinations could be made was limited only by the possibility of obtaining complete crystallization within a reasonable time. Thus Ab, An, was reheated many times before a constant value was reached. Ab, An, required 17 days and Ab, An, was not completely crystallized in any of our attempts. Crystalline albite was produced under other conditions.

The specific gravities of the glasses and of so many of the crystalline mixtures as we could obtain are tabulated below :

* Wied. Ann., xxiv, p. 327, 1885.

† Dana, System of Mineralogy, 6th ed., p. 314 et seq.

SPECIFIC GRAVITIES OF ARTIFICIAL CRYSTALLINE FELDSPARS.

An	Ab, An ₂	Ab, An ₂	Ab, An ₁	Ab, An ₁	Ab, An ₁	Ab (First Determination)	Ab (Corrected)
{ 2.764	{ 2.734	{ 2.710	{ 2.680	{ 2.660	{ 2.650	c { 2.620	2.607
{ 2.765	{ 2.734	{ 2.708	{ 2.680	{ 2.660	{ 2.648	c { 2.620	
				{ 2.660			
a 2.767	a { 2.732	b { 2.710	b { 2.679	b { 2.659		d { 2.614	2.601
	{ 2.732	{ 2.710	{ 2.677	{ 2.660		d { 2.615	
							f 2.614
	a 2.734					e 2.604	g 2.605
Mean 2.765	2.733	2.710	2.679	2.660	2.649		2.604

SPECIFIC GRAVITIES OF FELDSPAR GLASSES.

{ 2.700	{ 2.647	{ 2.593	{ 2.533	{ 2.482	{ 2.458	{ 2.383
{ 2.700	{ 2.649	{ 2.594	{ 2.534	{ 2.482	{ 2.459	{ 2.382
	{ 2.648	{ 2.591		a 2.485		
	{ 2.647	{ 2.591				
	{ 2.648	{ 2.590				
	{ 2.649	{ 2.588				
	{ 2.647					
	{ 2.647					
Mean 2.700	2.648	2.591	2.533	2.483	2.458	2.382

Determinations in duplicate are enclosed in brackets.

a. Another preparation.

b. Same material reheated for several days at temperatures about 150° below the melting point.

c. Contained about 0.8 per cent of sodium tungstate.

d. Purified by warming with dilute hydrochloric acid, then with water, and afterwards with ammonia.

e. Purified by fusion with acid sodium sulphate.

f. Assuming the residual tungsten to be present as Na₂WO₄.

g. Assuming the residual tungsten to be present as WO₃.

Sintering.—Incidental to this work upon the relation between the feldspars, we made a great many observations upon the sintering of powdered minerals, both crystalline and vitreous, of natural and artificial composition. While the results have not enabled us to offer positive conclusions of importance, they are worth a note in passing,

Powdered glasses sinter slowly or rapidly several hundred degrees below the melting temperature of crystals of the same composition. When the viscosity is relatively slight (anorthite) crystallization begins at a low temperature and proceeds very rapidly, the sintering probably being due to the interweaving of the crystal fibers during their formation. In viscous glasses (albite) sintering also begins at low temperatures,—

the finer the powder and the slower the heating, the earlier the first traces appear. Long continued heating, even at very low temperatures (700°), yields a perfectly continuous cake (except for the included bubbles) the surface area of which constantly tends toward a minimum. There is no doubt that the sintering of powdered glasses is due to flow in the under-cooled liquid and is a phenomenon in liquid viscosity. All the feldspar glasses sintered readily between 700° and 900° , depending on the fineness of the powder and the time.

Powdered crystalline feldspars do not sinter readily below their melting temperature. Indeed we were at first inclined to the view that when only pure, dry, stable crystals are present, they do not sinter however finely they be powdered. We observed the phenomenon in natural albite at 1000° but the crystals were not wholly free from inclusions which may have caused chemical reactions resulting in cementation. Crystalline fluorite also sinters 300° below its melting point, but here we were able to establish a decomposition. Acid fumes were evolved during the experiment and the sintered cake contained 1 per cent of free lime. Our final experiments with long continued heating for specific gravity determinations, however, showed that the purest feldspars we could prepare, even after they had reached their maximum density, still sinter very slowly. Thus Ab, An , powder, which was shown by a determination of its specific gravity to be holocrystalline, formed a compact chalky mass in four hours at a temperature about 150° below its melting point; in three days it was as hard as porcelain. Other feldspars showed the same behavior. It is hardly possible that inhomogeneities sufficient to produce diffusion between portions of different concentration, could have existed in these charges. There is considerable indication that some of the crystalline nuclei grow at the expense of others—perhaps through exceedingly slow sublimation—which may account for it.

We made repeated attempts to locate some fixed sintering point which should be characteristic of a particular material by means of continuous measurements of the electrical conductivity, but they all indicated that no such point existed. The conductivity of a dry powder increases enormously after sintering begins and would therefore seem to offer a most sensitive test, but the phenomenon is altogether gradual even with a crystalline feldspar containing only a small percentage of glass. We purpose to extend these observations to other substances.

Conclusions.—It now remains for us to gather the results together and to draw such conclusions as they appear to justify.

(1) If the melting points are now plotted in a system of

which they form the ordinates, while the percentage compositions of the different feldspars form the abscissas (fig. 12), we discover, within the limits of accuracy of possible measurement at these temperatures, a nearly linear relation: the melting point varies very closely with the composition. We have no maximum, no minimum, no branching of the curve, but from each fusion there separates a solid phase of the same composition as the vitreous matrix. In Ab, An , it will be remembered that this was proved by the separation and analysis of the two phases; in Ab, An , partial crystallization was accomplished in the first cooling and the remainder in a subse-

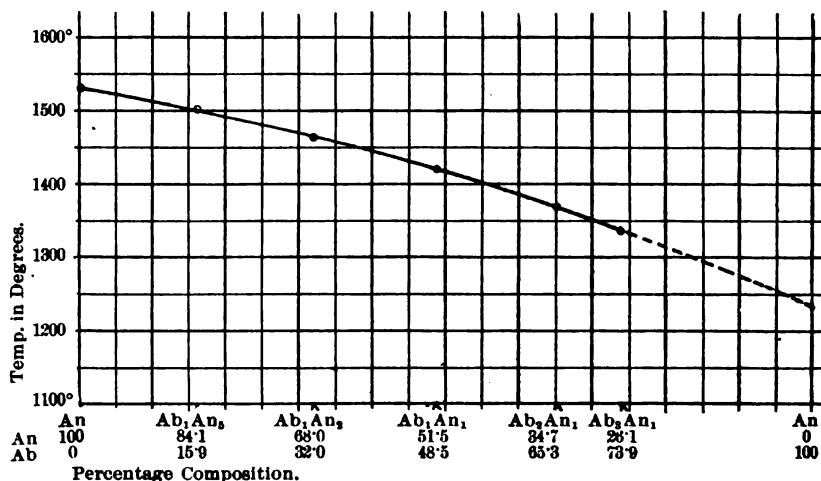


FIG. 12.

quent reheating and cooling, the two groups of crystals proving optically identical; a small quantity of Ab, An , which admits of absolute identification optically, was crystallized out of a melt of that composition and readily recognized. Moreover, evidence to show that the same phase always separated was likewise presented.

Stated in this way, the relation appears to be a simple additive one in which liquid and solid phases of like composition are stable in all proportions of the components and behave like a series of separate feldspars. But as soon as we consider it with reference to the laws of solution and the phase rule, it can not be explained in this simple way.

First of all, the phase rule tells us at once that we can have no true compound here between the components albite and anorthite, for such a compound would mean one more component and an additional phase in every solution before equilibrium could be established. Moreover, if the mixture had

been eutectic in character, the component (albite or anorthite) which happened to be in excess would have crystallized out in each case, causing a continual change in the composition of the remaining glass until the eutectic proportion was reached and the resulting charge would have contained only crystals of one (or, in case of hysteresis, both) of the components and the eutectic. Our curve is continuous and the resulting charges homogeneous for all proportions of the components. Lane's suggestion* that the triclinic feldspars from a eutectic series in which the eutectic proportion is at or near Ab,An, is therefore not borne out by our experiments.

Laying aside the eutectic mixture, and passing over to solutions of components which are miscible in many or all proportions, we find a small number of examples, chiefly organic compounds, which have been studied as types by Roozeboom, Küster, Bodländer, Garelli, Bruni, Van Eyk and others, among which our series appears to fall.

Laws of Solutions.—From the physico-chemical standpoint, the case we now have in hand closely resembles Küster's problem of 1891.† His measurements were made upon mixtures of organic compounds of low melting point, while ours reached a maximum temperature of 1532° , but we have, between albite and anorthite, an exactly similar series of solid solutions the melting points‡ of which change in nearly linear relation to the percentage of the two compounds which enter into their composition.

This simple linear relation was called by Küster perfect isomorphism, and he formulated the "Rule" which has since borne his name, that the solidifying point of an isomorphous mixture lies on a straight line joining the melting points of the components and can be calculated from the percentage composition of the mixture. If this line proved to be slightly concave or convex, as it did in most cases, imperfect isomorphism was assigned as the cause. To this rule an objection was raised by Garelli§ and elaborated by Bodländer||—if the solid solution behaves like other solutions, a small quantity of component *B* added to component *A* can only lower the solidifying point of *A* when the solid phase is richer in *A* than the liquid phase. The reasoning is this (Bodländer): let x , (fig. 13) be the vapor tension curve of component *A* in the liquid state, y , the solidifying point (t_s) of *A*, and z , the vapor tension

* Lane, *Journal of Geology*, XII, ii, p. 83, 1904.

† F. W. Küster, *Zeitschr. für Phys. Chem.*, viii, p. 577, 1891.

‡ Küster measured solidifying points, but we have pointed out above that such measurements lead to no positive result in liquids of such viscosity as the feldspars in which equilibrium is not established during solidification. Undercooling rarely appeared at all in Küster's cases.

§ F. Garelli, *La Gazzetta Chimica Italiana*, xxvi, p. 263, 1894.

|| Bodländer, *Neues Jahrb. f. Min., Beilage*, Bd. xii, p. 52, 1899.

curve of solid *A*. Now if a small quantity of *B* is added and the solid phase which crystallizes out contains the same proportions of *A* and *B* as the liquid mixture in which it formed, the vapor tensions of the liquid and solid phases must have been lowered equally and the solidifying point will fall at y_2 with the same temperature as the pure solvent. (Equality of vapor tension in the solid and liquid phases determines the temperature of change of state.) If *A* crystallizes alone from *A* + *B*, the vapor-tension curve will continue on to z_1 and the temperature of solidification fall to t_2 ; while if the solid phase contains both components but is richer in *A* than the liquid phase, solidification will occur at an intermediate point.

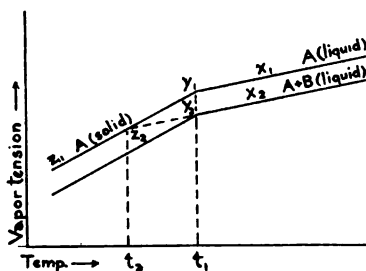


FIG. 13.

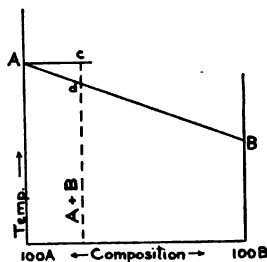


FIG. 14.

Fig. 14 will serve to show the crucial character of the issue raised. The ordinates represent temperatures, and the abscissas percentages of *A* and *B*. Küster finds his solid and liquid phases identical in composition within the limits of experimental error and the solidifying temperature on the line *AB* at a point which can be determined from the proportions of the components—at *d* for example. But the laws of dilute solutions tell us that if the phases are identical in composition, the solidifying point of *A* + *B* must fall at *c*, i. e. must remain the same as for pure *A*.

The temperatures at which Küster's observations were made and their painstaking character leave no doubt as to the validity of the experimental fact. Neither can it be objected that Küster's solutions were not sufficiently dilute to reveal the true relation, for the observations upon naphthalene and β -naphthol have been repeated by Bruni* with very dilute solutions of one of the components in the other, and completely verified.

Now the laws of solutions hold for solid solutions even for moderately high concentrations (Bodländer) when the components are not isomorphous, and on the other hand even liquid crystals, when isomorphous, follow Küster's Rule more nearly than the law of solutions.

* G. Bruni, *Atti della Reale Accademia dei Lincei*, series 5, vii, p. 138, 1898.

An extended discussion of existing data from this standpoint would involve us in unnecessary detail, but there can be no question that Kuster's Rule represents the data which have been gathered upon isomorphous mixtures—at least approximately—while the laws of dilute solutions appear to fail of application there. On the other side, the Rule admits of no independent theoretical derivation. Van't Hoff* suggests that judgment be suspended pending the accumulation of further data and intimates that the close similarity of chemical composition and molecular structure in compounds which form isomorphous mixtures, gives them an unusually close interrelation, and their influence one upon the other may render a simple theoretical treatment very difficult.

Our case is especially interesting when considered from this standpoint, but it distinctly emphasizes the difficulty rather than helping toward its solution: (1) Although the chemical reactions of albite and anorthite are not of such a character as to prove or disprove a close analogy between them, a comparison of their formulas certainly does not suggest an isomorphous relation. If their formula weights represent true molecules, they possess the same number of atoms to the molecule ($\text{NaAlSi}_3\text{O}_8$, $\text{CaAl}_2\text{Si}_2\text{O}_8$) and the group Si_2O_5 in common, but the remaining atoms taken separately are not mutually replaceable. (2) The melting points of the components in the feldspar series are very far apart—more than 300° —while Küster's organic mixtures were all included within a narrow temperature interval (2° to 56°). For reasons which will appear presently, both Garelli† and Roozeboom have pointed out that the farther apart the melting points of the components, the less probable is the linear relation. (3) The homogeneity of the solid phase is established within 1 per cent by the optical examination of the slides. Moreover separate chemical analyses of the solid and liquid phases of the mixtures Ab, An, in an exceptionally favorable case showed still closer identity of composition.

It appears altogether improbable that the laws of solutions can apply in the face of so extreme a controverting case.

If it has proved difficult to bring the isomorphous mixture within the general laws of solutions, a most satisfactory theoretical derivation of the conditions of equilibrium in such mixtures has been developed by Roozeboom. No other principle is required than the second law of thermodynamics as applied to solutions by Gibbs:—A system of substances will be in equilibrium for a particular pressure when the thermodynamic potential (ζ -function) of the system is a minimum. The scheme of representation is the graphical one proposed by

* Van't Hoff, *Vorlesungen üb. Theoret. u. Phys. Chem.* (Braunschweig 1901.) Part II, p. 64.

† F. Garelli, *loc. cit.*

van Ryn van Alkemade* and is itself a powerful instrument of analysis in this field.

Roozeboom distinguishes three general classes of isomorphous mixtures:

- (1) The components are miscible in all proportions from 0 to 100 per cent in both solid and liquid phases.
- (2) Miscibility is limited to certain concentrations.
- (3) More than one type of crystal occurs.

In the feldspars we are concerned with the first class only, but here also Roozeboom distinguishes three possible types:

Type I. Melting (or solidifying) points of the mixtures lie on a continuous curve joining the melting points of the components and containing neither maximum nor minimum.

Type II. The curve contains a maximum.

Type III. The curve contains a minimum.

* Zeitschr. f. Phys. Chem., xi, p. 289, 1893.

Except for the suggestions of Vogt to which reference has been made, this method seems not to have been utilized for the study of mineral solutions before. A brief outline of it will therefore be given here.

In a system of rectilinear coördinates (fig. 15) the ordinates may represent

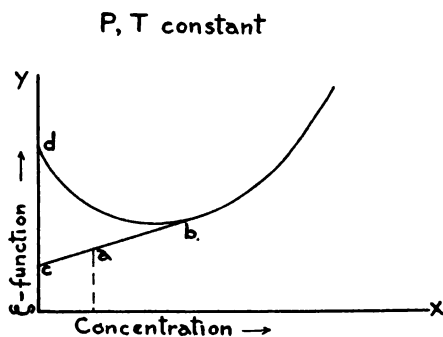


FIG. 15.

the potential of a particular system—(Gibbs' ζ -function, not directly measurable) and the abscissas the number of gram-molecules of solvent (water for example) supposed to contain 1 gr. mol. of solute. In other words, every point of the curve represents a solution of which the x coördinate is concentration and the y coördinate the potential. The conditions of pressure and temperature are assumed constant for a particular diagram.

Every such curve for substances soluble in all proportions will be convex downward, otherwise there would be some particular point on the curve which would not represent a minimum potential for a particular composition and the solution would tend to separate into two, the mean potential of which would be lower.

The condition for equilibrium between such a solution and its solid phase (pure salt) may now be readily found. Lay off on the ζ -axis a distance equal to the potential of the solid salt and from the point so obtained draw a tangent to the curve. This tangent is the locus of minimum potential (stable systems) for any composition. At the point a for example, we have a saturated solution containing the number of gr.-mol. of solvent indicated by the corresponding abscissa and the proportion $\frac{ac}{cb}$ of salt, the balance of the salt remaining in solid phase. At b we have the saturated solution with all the salt included; to the left of b upon the curve, supersaturated solution; and to the right unsaturated solution. With increase of temperature the form of the curve changes and c approaches d , the melting point of the salt.

These types are for the moment purely hypothetical and are a product of the method of analysis, though they are being rapidly identified for various isomorphous pairs by pupils of Roozeboom and by others.

The method of reasoning which yields these three possible types will be briefly described with the help of the van Alkemade graphical analysis:

If we indicate the potential (ζ) of a particular mixture by the length of the ordinate (fig. 16), and the number of molecules of A and B by subdividing the horizontal axis ($A+B=100$) in the proper proportion, assuming atmospheric pressure and constant temperature for each diagram, then every point within the coördinates represents a particular phase of known composition and potential. Suppose now (Roozeboom) a temperature is assumed above the melting point of the higher-melting component, clearly, whatever the composition, only the liquid phase can have a stable existence. If potential difference represents the measure of the tendency to change and the tendency of all change is toward the minimum potential, for this temperature all change will be toward the liquid, and the potential of a solid, if one existed there, would be greater than that of the liquid for all compositions—hence the curve S (solid) above the curve L (liquid) throughout.

Suppose the potential to be lowered to a point where crystallization can begin, the tendency to melt no longer obtains for all compositions, the two curves will be displaced relatively and, being of different form, will intersect. Draw a common tangent to the two curves and apply van Alkemade's reasoning above noted. The trend of the potential of both phases between the points of tangency, i. e. of all mixtures between these limits of composition, is toward the minimum represented by this tangent. Crystallization will then begin at a

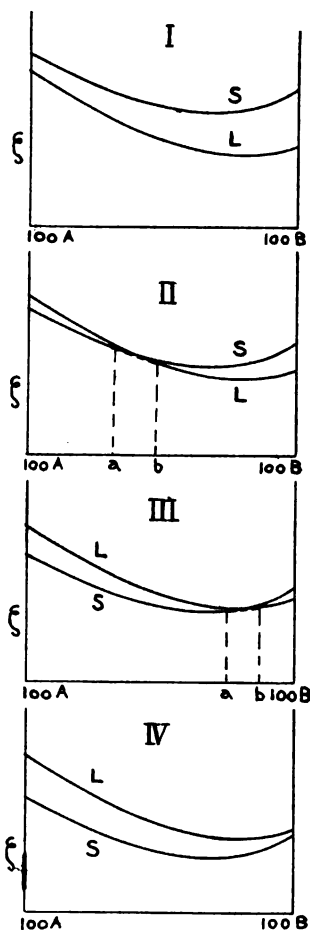


FIG. 16.

(fig. 16, II) with the mixture richest in the higher melting component, crystals of composition *a* will be in equilibrium with the liquid phase *b* in all proportions and solidification (or

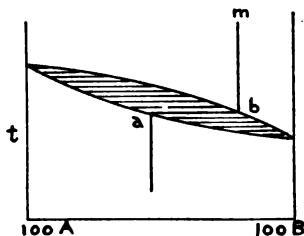


FIG. 17.

melting) will not take place at a single temperature but through a range of temperature. If we now plot the length of the abscissa corresponding to *ab* in a separate diagram with the observed temperature range of solidification, adding all the other possible cases which will arise from the continued displacement of the ζ -curves, we arrive at the accompanying diagram (fig. 17) of Roozeboom's type I. Types II and III appear in the same way when the form of the ζ -curves changes as indicated in figs. 18 and 19.

The physical side of the system of reasoning is readily inferred from the figures. If we start with a mixture of the composition indicated by *m*, (fig. 20) and temperature above the melting point, crystallization will begin at *a*, the separating crystals will have the composition *b*, while that of the remaining melt approaches *d*. Upon cooling to *e*, solidification ends with crystals of this composition. Melting is exactly the reverse operation. Whether these first crystals of composition *b* remain stable as such or undergo solid transformation or wholly or partly redissolve, appears to remain undetermined in any general way by Roozeboom's theory and may be radically influenced by accompanying phenomena like viscosity and undercooling: if a liquid mixture of composition *a* undercools to *e* before crystallization begins, crystals of composition *e* will appear *and no others* (provided the release of heat of fusion does not raise the temperature above *e*). Such a situation is certainly unavoidable in viscous mixtures like the feldspars and accounts very well for the homogeneous solidification observed by us. This would classify the feldspars with type I of Roozeboom's series. A comparison of our melting point curve with figs. 17, 18 and 19 shows this to be the only type under which it could possibly fall. There is no trace of a maximum or minimum in the feldspar curve. Vogt's expectation that they would fall under type 3 therefore fails of fulfilment from our experiments.

That our curve so closely resembles one branch of Roozeboom's typical curve is remarkable. The difficulties of observation, in those portions of the curve where the viscosity becomes so disturbing, are too great to enable stress to be laid upon the form which our curve happens to take there, but

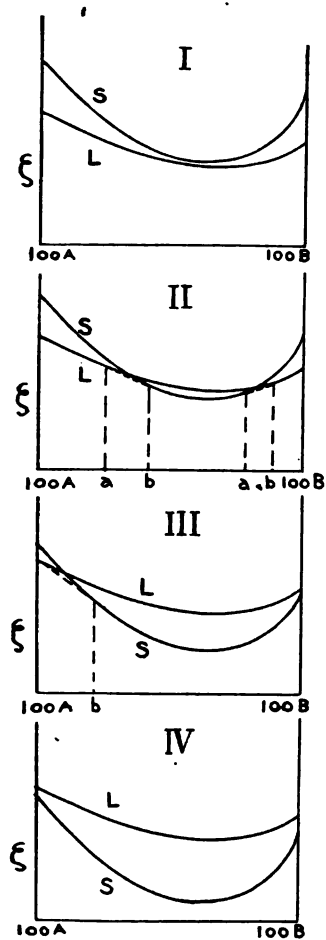


FIG. 18.

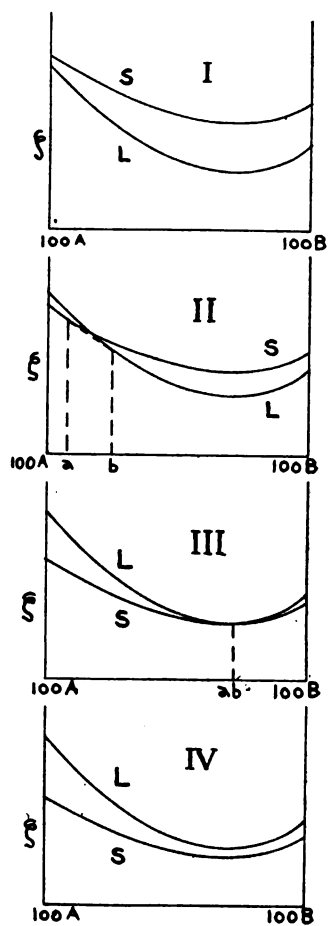
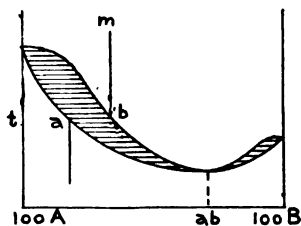
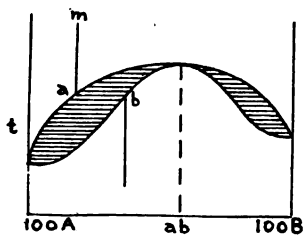


FIG. 19.



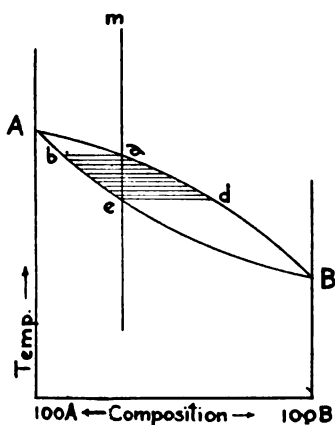


FIG. 20.

small quantity of the optically different feldspar, the fact that it could not be found in all the slides and that in one case a less calcic feldspar appeared, suggest that the inhomogeneity may have been of other origin—perhaps merely a consequence of the tremendous difficulty in mixing a homogeneous charge where ultraviscosity precludes stirring, for example. The chemical analyses of the solid and liquid phases, it will be remembered, showed identical composition within the limits of experimental error.

It is clear that if Roozeboom's theory is valid, the line of the melting points can not become perfectly straight unless the ζ -curves for the solid and the liquid phases can be superposed point for point throughout, i. e., are identical. This would mean that the energy content per gr.-mol. of solid and liquid phase was the same for all compositions, i. e. that all mixtures, and the components separately should have the same melting point,—a case which is known (Roozeboom, *d*- and *l*-camphor oxime) but is certainly confined to optical antipodes.

Another reason for supposing the case to be much less simple than a mere linear relation with equilibrium between solid and liquid phases of identical composition, appears at once from a direct application of the phase rule. A necessary condition for equilibrium in any mixture is that the number of phases exceed the number of components by two. If the solid and liquid phases are homogeneous, the number of phases (counting vapor) is only three and equilibrium can not obtain there.

Reviewing this discussion briefly: The triclinic feldspars are solid solutions and form together an isomorphous series. It is a sufficient condition for the latter that the curve of melting points is continuous (Bruni, loc. cit.). Like Küster's

near the anorthite end of the series its slight convexity is unquestionably real.

It should be added that Prof. Iddings has found slight traces of inhomogeneity (less than 1 per cent) in the slides of several of our intermediate feldspars. Crystals have been found which were evidently of the earliest formation and with one exception were more calcic than the body of the charge, as Roozeboom's theory would lead us to expect. The exception was an occurrence of tiny plates of Ab, An , discovered in a charge of Ab, An . The extremely

curves for organic compounds, the curve of melting points does not follow van't Hoff's law of dilute solid solutions and does approximate closely to a straight line joining the melting points of the components. The case appears to fall under type 1 of Roozeboom's theoretical classification of isomorphous mixtures, in which case the line can not become exactly straight unless the melting points of the components are nearly or quite identical, nor the solidification absolutely homogeneous without reducing the number of phases to three and destroying the equilibrium. The theory also accounts for an absence of sharpness in the intermediate melting points of the feldspars, but the fact that this lack of sharpness culminated in albite instead of terminating there shows that the viscosity was the chief factor in our difficulties from this cause. Albite was clearly shown to melt through a variable range of 150° or more, while the intermediate feldspar bytownite (Ab, An) melted almost as sharply as anorthite. The fact that practically no differences of composition could be detected in our melts we attribute to the effect of viscosity and consequent undercooling, which resulted in crystallization invariably taking place at much too low a temperature for equilibrium to become established between the solid and liquid phases at any stage of the crystallization process.

(2) When the specific gravities are plotted, like the melting points, as a function of the composition (fig. 21), the isomorphism of the feldspars is strongly confirmed. The curve indicates a perfectly continuous relation which the successful preparation of chemically pure albite enabled us to follow through to the end. The order of accuracy is also extraordinarily high throughout by reason of the chemical purity of all the preparations and the consistent effort made to obtain complete crystallization, even with the more viscous feldspars. Several of the charges were treated for two weeks or more consecutively, then removed for a determination, then replaced in the furnace for another week, in order that we might assure ourselves from the consistent reappearance of the same value that a maximum and therefore holocrystallization had been reached. It is of some practical importance to note in passing, that preparations which appeared completely crystalline in the slides frequently proved not to have reached their maximum specific gravity. It is very difficult to detect the last trace of glass with the microscope.

If our confidence in these determinations is justified, the form of the specific gravity curve is very significant. It was pointed out by Retgers* that if the isomorphous mixture is merely a "mechanical aggregate," the volume of which remains exactly equal to the sum of the volumes of the components, then the specific volume curve of the mixtures for percentages by weight

* J. W. Retgers, *Zeitschr. für Phys. Chem.*, iii, p. 507, 1889.

of the two components must be a straight line. He also offers a number of isomorphous pairs for which he finds the specific volume curves to be straight lines, in support of his hypothesis that this relation is general. Our values when plotted in this way (fig. 22) also give a straight line with maximum variations amounting to 0.005, which is probably not greater than the aggregate error in the syntheses and in the determinations of the specific gravity.

In spite of this apparent corroboration, it does not seem to us that Retgers was quite justified in assuming that this relation is entirely without limitation. The temperature at which the specific gravity is determined is so far below the temperature of solidification (in our case, more than 1,000°) that the density at 25° will depend to a considerable degree upon the coefficient of expansion of the material as well as upon composition or molecular structure. The coefficient of expansion will, in general, differ for different substances, and is not, in general, a linear function of the temperature. Considering Retgers' generalization in the light of these facts, the relation of the specific gravities at 25° would be necessarily continuous but not necessarily linear.

The specific gravities of the glasses are also plotted (fig. 21) to show the divergence from the line of the crystals toward the albite end of the series, i. e., as the percentage of albite increases, the density of the glass is diminished more than that of the crystals.

There is nothing new in the conception of isomorphism in the feldspars, but the positive character of our experimental results makes them of more than ordinary interest by reason of the fact that so good authorities on the subject as Fouqué and Lévy have passed upon it adversely on the basis of optical evidence derived from artificial preparations. More recently Viola,* has declared that the optical evidence is insufficient to prove isomorphism in the natural feldspars.

The melting points and specific gravities are brought together in a convenient table here.

Feldspar	An	Ab, An ₂	Ab, An ₃	Ab, An ₄	Ab, An ₅	Ab, An ₆	Ab
Melting temp.	1532°	1500°	1463°	1419°	1367°	1340°	
Sp. gr. (crystals)	2.765	2.733	2.710	2.679	2.660	2.649	2.605
Sp. gr. (glass)	2.700	2.648	2.591	2.533	2.483	2.458	2.382

(3) In the melting of albite and microcline we appear to have substantial evidence of a phenomenon which is unfamiliar both to physics and to mineralogy. Microscopic crystals of a homogeneous compound, when slowly heated, were shown to persist for 150° or more above where melting began, the amorphous melt remaining of the same order of viscosity as the rigidity of the crys-

* Loc. cit.

tals. By careful observation, curves were also obtained showing that the absorbed heat of fusion was distributed over this interval.

From the experimental standpoint a substance of this kind can hardly be said to have a melting point but passes gradually from crystalline to amorphous at temperatures which can be

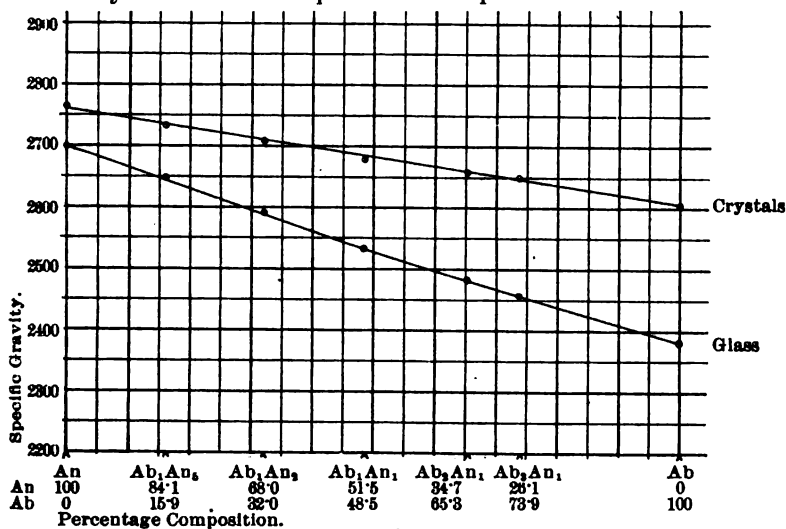


FIG. 21.

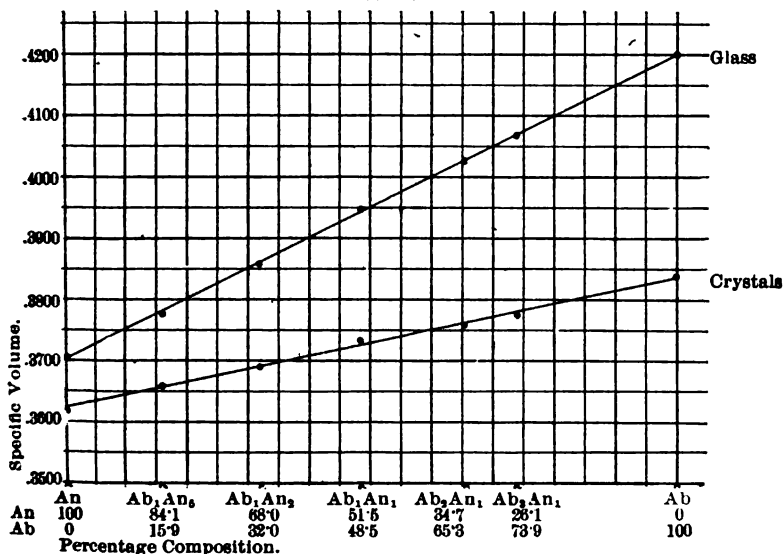


FIG. 22.

considerably varied by merely changing the rate of heating. In moderate charges of albite or orthoclase at atmospheric pressure this melting began so slowly that it was not possible to locate even approximately a lowest temperature for the beginning of the change of state. As a matter of definition, this minimum temperature above which melting will continue (for a given pressure) more or less rapidly according to the conditions, is the "melting point," whether it can be located or not, so far as the equilibrium of the system is concerned, and the crystals which continue to exist unmelted at higher temperatures appear to form a metastable phase, perhaps comparable with that of a crystalline solid when heated above the "Umwandlungstemperatur" without immediate change of crystal form. It is also possible that the mass is fluid when heated above the melting point but that deorientation of the molecules is delayed by viscosity. This metastable stage can easily extend over 150° in albite and orthoclase and would persist for days in the lower position of this range.

(4) We also found that viscous and poorly conducting melts which solidify only after considerable undercooling, do not give constant solidifying points. The solidifying point must not be used, therefore, without great caution as a physical constant; it bears no relation whatever to the melting point unless equilibrium is reestablished before solidification is complete—a condition which rarely obtains and often can not be produced in viscous mineral melts. Especial attention is directed to this because of the importance of the lowering of the solidifying point in the study of solutions, and the possibility of its application to mineral solutions recently suggested by Vogt.*

(5) Incidental to the experimental work upon the feldspars we were able to establish the fact that there are no differences of density in the feldspar glasses due to the rate of cooling, which are greater than our errors of observation (± 0.001). Also that powdered feldspar glasses sinter tightly at temperatures as low as 700°,—a phenomenon which we ascribe to flow in the undercooled liquid. Pure, dry, crystalline feldspars also sinter at least 150° below their melting temperature, but very slowly. This may be due to certain crystalline nuclei growing at the expense of others; perhaps through exceedingly slow sublimation.

Also that powdered feldspars, when exposed to the atmosphere, adsorb moisture, in quantities of an order of magnitude equal to those usually quoted in analyses (Dana's System of Mineralogy, p. 314). It is therefore altogether possible that the significance of this moisture has been mistaken. It cannot be completely driven off below a red heat.

Geophysical Laboratory, Carnegie Institution,
Washington, D. C., November, 1904.

*J. H. L. Vogt, loc. cit.

ART. VIII. — *On the Progress of the Albatross Expedition to the Eastern Pacific*; by ALEXANDER AGASSIZ.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Lima, Nov. 28, 1904.]

THE Albatross, under command of Lieut. Commander L. M. Garrett, left San Francisco on the 6th of October and arrived at Panama the 22d. On her way along the coast Professor C. A. Kofoid took advantage of the opportunity for making surface hauls with the tow nets as well as vertical hauls, generally to a depth of 300 fathoms. A large amount of pelagic material was thus collected, not at a great distance from the coast however. Off Mariato Point the Albatross made two hauls in the vicinity of the stations where in 1891 she found "modern green sand," in about 500 and 700 fathoms. It was interesting to find the green sand again, as the specimens collected in 1891 were lost in transit to Washington. I am fortunate in having as assistant for this trip Professor Kofoid, who has had great experience in studying the Protozoa both in fresh water and at sea. He has been given charge of the collection of Radiolarians and Diatoms and of other minute pelagic organisms; and he will prepare a report on the results of that branch of the Expedition.

The Albatross arrived at Panama on the 22d, she was coaled and provisioned at once, on my arrival at Panama on the 1st of November I found her ready for sea, and on the 2d we left for Mariato Point to make a few additional trawl hauls in the region of the green sand. In both the hauls made off Mariato Point green sand was found, but not in the quantity obtained in 1891.

From Mariato Point we made a straight line of soundings towards Chatham Island in the Galapagos, intersecting the ring of soundings we made northeast of the Islands in 1891. The deepest point of the line (1900 fathoms) was found about 100 miles S.W. of Mariato Point. The bottom then continued to show about 1700 fathoms for nearly 200 miles and then shoaled very gradually to 1418 fathoms about 80 miles from Chatham Island. From this point it sloped quite rapidly, the 1000-fathom line being not more than 60 miles from Chatham Island. We ran a short line south of Hood Island and found a somewhat steeper slope to that face of the Galapagos, reaching over 1700 fathoms in a distance of less than 50 miles; the bottom then remained comparatively flat, attaining a depth of 2000 fathoms about 100 miles farther south. This depth we carried eastward on a line to Aguja Point. When half way the soundings had increased to over 2200 fathoms, and remained at about that depth to within 60 miles of the

coast, when the depth rapidly shoaled. From Aguja Point we ran a line of soundings to the S.W. to a point about 675 miles west of Callao; on this line the depths gradually increased from 2200 fathoms, 100 miles off the Point, to nearly 2500 fathoms. On running east to Callao the depth soon increased to about 2600 fathoms, and at a distance of about 80 miles off Callao we dropped into the Milne-Edwards Deep and found a depth of over 3200 fathoms. We spent a couple of days in developing this Deep, making soundings of 1490, 2845, 458, 1949, 2338, and 3120 fathoms; showing a great irregularity of the bottom within a comparatively limited area of less than sixty miles in diameter. Thus far all our soundings have been made with the Lucas Sounding Machine.

In the Panamic Basin to the northeast of the Galapagos we trawled only off Mariato Point, but we occupied ten stations with the tow nets, hauling both at the surface and at 300 fathoms, and vertically from that depth; we also continued this pelagic work at nearly all the stations (35) from the Galapagos to Callao.

When off Chatham Island we began to trawl, and used the tow nets regularly, occupying 20 stations. The nets were in charge of Mr. F. M. Chamberlain. The pelagic collections, as a whole, are remarkably rich. They are especially noteworthy for the great variety and number of pelagic fishes obtained inside the 300-fathom line at a considerable distance from shore—from 300 to 650 miles. Many of these fishes had been considered as true deep-sea fishes, to be obtained only in the trawl when dredging between 1000 and 1500 fathoms or more. On one occasion the tow net brought up from 300 fathoms, the depth being 1752 fathoms, no less than 12 species of fishes; of some species of *Myctophum* we obtained 18 specimens; of another, 37; of a third, 45; in all nearly 150 specimens. On other occasions it was not uncommon to obtain 8 or 10 species, and from 50 to 100 specimens. Among the most interesting types obtained in the tow net I may mention as coming from less than 300 fathoms *Stylophthalmus* and *Dissoma*, both of which Chun considers as deep-sea fishes, found in depths of 600 to 4000 meters; also a species of *Eurypharynx* obtained for the first time in the Pacific. *Stylophthalmus* I had caught in the tow net also in 1900, during the tropical Pacific Expedition of the Albatross, in depths of less than 300 fathoms. In the lines we ran across the great northerly current which sweeps along the coasts of Peru and Chili and is deflected westward at the easterly corner of the Galapagos Islands, we obtained with the tow nets an unusually rich pelagic fauna at depths less than 300 fathoms. We collected a number of Schizopods, among them many beautifully colored *Gnatheuphausiæ*, pelagic *Macrurans*; huge, brilliant red Copepods, as well as many other species of blue,

gray, mottled and banded Copepods. Lucifer and Sergestes were abundant in many of our hauls. Many species of Amphipods were collected, Hyarids without number, especially where the surface hauls were made among masses of Salpæ, which, on several occasions, formed a jelly of Tunicates. Several species of Phronimæ also occurred constantly in the tow nets. Sagittæ were very numerous, a large orange species being noteworthy. Several species of Tomopteris, some of large size and brilliantly colored, violet or carmine with yellow flappers, and two species of Pelagonemerteans. Two species of orange-colored Ostracods were also common, one having a carapace with a long spiny appendage. We obtained several species of Pelagic Cephalopods, Cranchia and Taonis among them. Two species of Doliolum also occurred, but they were never as abundant as the Salpæ, two species of which often constituted the whole contents of the net.

In the surface and deeper tows we procured also a number of Acalephs. We have thus far collected more than 50 species of Medusæ and Siphonophores, many of which have been figured by Mr. Bigelow, differing from those of the 1891 Expedition. Atollæ and other deep-sea Medusæ were common within the 300 fathom line.

The Salpæ guts gave us, in addition to the finer tow nets, immense collections of Radiolarians, Diatoms, and Dinoflagellata, many of which have been considered to live at great depth and upon the bottom. The number of Diatoms found in this tropical region is most interesting. They have usually been considered as characteristic of more temperate and colder regions. On several occasions the surface waters were greatly discolored by their presence, and the extent of their influence on the bottom deposits is shown by the discovery of a number of localities where the bottom samples at depths from 1490 to 2845 fathoms, in the track of the great Peruvian current, formed a true infusorial earth.

The tow nets also contained many species of Hyalæa, Cymbulium, Styliolus, Cleodora, Tiedemannia, Clio, and the like. On one occasion the mass of the pelagic hauls consisted entirely of small brown Copepods, the contents of the tow nets looking like sago soup. Another time Sagittæ, Salpæ, Diliolum and Liriope, all most transparent forms, formed the bulk of the tow net's catch. Again another time, Firoloides and Carinarias constituted the bulk of the haul. These catches, coming on successive days or interrupted with hauls of more than mediocre quality, show how hopeless it is at sea to make any quantitative analysis of the pelagic fauna and flora at any one station within the influence of such a great oceanic current as the Chili and Peruvian stream.

Hauls of the trawl made at the western extremity of our lines brought us within the area of the manganese nodules, with its radiolarian ooze mud, Cetacean earbones and beaks of Cephalopods; nothing could stand the damaging work of these nodules in grinding to pieces all the animal life the trawl may have obtained. Down to the depth of 2200 fathoms or so the bottom was constituted of Globigerina ooze, its character being more or less hidden when near the coast by the amount of detrital matter and terrigenous deposits which have drifted out to sea.

North of the Galapagos we found vegetable matter at nearly all the stations, and between the Galapagos and Callao such material was not uncommon in the trawl.

Beyond the line of 2200 fathoms dead Radiolarians became quite abundant on the bottom, as well as in the mud of the manganese nodules, though among the nodules it was not uncommon to find an occasional Biloculina. Many of the dead Radiolarians found on the bottom Mr. Kofoid obtained from the guts of Salpæ swimming near the surface or within the 300 fathom line in the tow nets sent to that depth. The same is the case with many of the Dinoflagellata which have been considered as deep-sea types. In our tow nets from 300 fathoms we found very commonly Tuscarora, Tuscarosa, Aulospira and others. In depths of 300 fathoms to the surface, the tow net was rich in Tintinnidæ, either dead or moribund Planktionellæ, and Dinoflagellata. Among the Dinoflagellata there were 10 species of Ceratium, 9 of Peridiniidæ, Goniauxia, Phalacrona, Pyrocystis, Cytrococyla, Undella and Dictiocystus. On the surface Planktionella sol predominates, with Asteromphale, Bidolphia, and Sunidia thalassothrix. Among the Dinoflagellata we obtained 12 species of Ceratium, 5 of Peridinium and 22 species of other Peridiniidæ; among the Tintinnidæ were a number of Sticholonga; among the Acantheriæ were especially to be noticed Acanthometra, Acanthostaurus, Amphilonche, Collozoum, Thalassicola, and a number of Chirospira Murrayana and a few Challengeridæ.

Our trawls brought up from the bottom many interesting fishes, among which I may mention Benthoptemis, Ipnots, and a few bat fishes, all, thus far, described by Mr. Garman from the 1891 Expedition. I may mention also a Chimæra, different from the Chili species. The fishes have been admirably cared for by Dr. J. C. Thompson, U. S. N.

Among the Crustacea, Lithodes, Munidopsis and many Macrurans, all well known species of the 1891 Expedition, we found a few Mollusks, and a few interesting genera of Tubiculous Annelids. Compared to the 1891 Expedition, few starfishes and brittle stars were obtained, and still fewer Sea Urchins, only one species of Aceste and one of Aerope, a

marked contrast to the numerous Echini collected in the Panamic Basin in 1891. We obtained, however, a magnificent collection of Holothurians, nearly every species occurring in the Panamic Basin being found in numbers in our track south of the Galapagos, in the wake of the great Chili-Peruvian current and at considerable depths. On one occasion, at station 4647, in 2005 fathoms, we obtained no less than 16 species of Holothurians, among them brilliantly colored Benthodytes, Psychropotes, Scotoplanes, Euphronides, and the like. At station 4670, in 3209 fathoms, we obtained 6 species of Holothurians. At station 4672, in 2845 fathoms, we obtained also very many specimens of three species of Ankyroderma, a large Deima, 2 species of Scotoplanes, 2 of Psychropotes, with a number of young stages of that genus, repeating thus the experience of the Challenger, which found Holothurians at great depth, in abundance not only in the number of specimens but also of species, though the Challenger did not in any locality obtain as many as we did at station 4647. Mr. Westergren made a number of sketches of the species which were not obtained in the 1891 Expedition. We also collected in the trawl a number of deep-sea Actinians, none different, however, from genera previously found in the Panamic district. We obtained also a few Pennatulids, Gorgonians, and Antipathes, and a very considerable number of silicious sponges, usually associated with the Holothurians found in deep water in the track of the Peruvian current. In the track of the current at not too great distances from the coast we invariably brought, even from very considerable depths, sticks and twigs and fragments of vegetable matter. On two occasions we brought up in the trawl specimens of Octacnemus. The trawl had been working at 2235 and at 2222 fathoms. Both Moseley and Herdman described this interesting Ascidian as attached to the bottom by a small peduncle. While the presence of the peduncle cannot be denied, yet its attachment, if attached at all, must be of the slightest, its transparent, slightly translucent body, with its eight large lobes, suggesting rather a pelagic type than a sedentary form. This Ascidian was discovered by the Challenger west of Valparaiso.

Mr. Chamberlain made two daily observations of the density of the water, and found the same discrepancies between our observations and those of 1891, and those given by the Challenger and in the German Atlas of the Pacific Ocean. Whenever we took a serial temperature, he also determined the density at 800 fathoms. We occupied six stations for the serial temperatures, two on the western termini of the lines normal to the coast across the great Peruvian current, two in the center of the current, and two at a moderate distance from the coast. These serials developed an unusually rapid fall in the tem-

perature between the surface and 50 fathoms—nearly 12° at the western extremity of the northern line, the temperature having dropped from 71.7° at the surface to 59.2° . At 200 fathoms it was 51° , and at 600 fathoms it had dropped to 40.7° , the bottom temperature at 2005 fathoms being 36.4° . The temperature of the station in the central part of the current in 2235 fathoms agreed with the western series. At the eastern part of the line in 2222 fathoms, with a bottom temperature of 36.4° , the surface being only 67° , we found again a close agreement at 50 and 100 fathoms, the lower depths at 400 and 600 fathoms being from one to two degrees warmer than the outer temperatures. On taking a serial from the surface to 100 fathoms, we found that the greatest drop in temperature took place between 5 and 30 fathoms.

The temperatures of a line running due west from Callao showed a very close agreement both at the western end of the line about 780 miles from the coast and in the central part of the line, as well as in the shore station about 80 miles from the coast in 3209 fathoms. The bottom temperature in nearly all the depths we sounded was 36° , a high temperature for that depth. I do not make at present any comparison with the serials taken in the Panamic District in 1891 until we shall have completed our lines to the south and to the west.

We leave for Easter Island on the 3d of December, where we shall coal, and from there go to the Galapagos and thence to Manga Reva and Acapulco, where we ought to arrive in the early days of March.

The changes made in the working apparatus of the Albatross under the superintendence of Lieutenant Franklin Swift, U. S. Navy, have proved most satisfactory. The alterations in the main drum and the device for preventing the piling of the wire on the serging drum and the accompanying shock, have greatly reduced the risk of breaking the wire rope when trawling at great depths. The wire rope has proved an excellent piece of workmanship, and has worked admirably in the comparatively deep water in which most of our trawling has been done thus far. A new dredging boom has also been installed, and everything relating to the equipment of the Albatross has been carefully overhauled.

Lieut. Commander L. M. Garrett has been indefatigable in his interest for the Expedition; the officers and crew have been devoted to their work; and the members of the scientific staff have carried out most faithfully their duties of preparing and preserving the collections thus far made.

We hoped to be docked at Callao, but owing to the prolonged occupation of the dock by a disabled steamer and the uncertainty of its becoming free within reasonable time, we decided to proceed without further delay to Easter Island and continue the Expedition as we are.

ART. IX.—*Measurement of Self-Inductance*; by J. B. WHITEHEAD and H. D. HILL.

THE absolute measurement and comparison of self-inductance has within the last few years become a problem of increasing importance. The best known method and that most generally used is the Rayleigh method. However, this necessitates very intelligent and careful work to obtain results concordant to one per cent. What seem to be the most accurate methods are various modifications of the Wheatstone bridge using alternating currents with an electro-dynamometer, telephone, or optical telephone as the measuring instrument.

In January, 1898, Professor Rowland* published a brief description of some twenty-six methods for the measurements and comparison of self-inductance capacity and mutual inductance. These methods are mostly of the Wheatstone bridge type and depend upon the use of an alternating current and an electro-dynamometer. As only a few of them have hitherto been tried, it was deemed desirable to systematically test them and determine their value, particularly in regard to the measurement of self-inductance. Such is the aim of the present investigation.

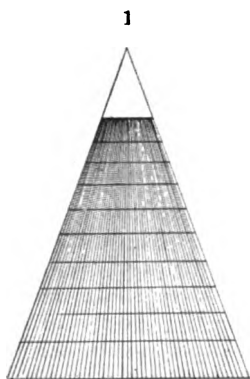
Source of current and frequency determination.

Since the value of the self-inductance or capacity as given by many of the methods depends upon the square of the current frequency, it was necessary to secure a current of harmonic wave form whose period was as constant as possible, and to devise a method of accurately determining that period at the moment of adjustment. This was very satisfactorily accomplished. In the deduction of the formulæ for all the methods the assumption is made that we have a simple harmonic electromotive force. In general an alternating current supplied by a dynamo has not only its fundamental period but also the odd upper partials. However, a generator constructed without too much iron and properly wound, if the field is not very strongly excited, will give a very good sine wave; especially if the resistance in the circuit contains self-inductance and no iron. These requirements were well satisfied by the dynamo used, which gave a very good sine wave. The alternator was constructed at the University. Its armature consisted of twelve coils fastened flat on a German silver plate revolving between twelve field pieces producing six poles. This dynamo was coupled directly to a direct current Crocker-Wheeler

* Phil. Mag. [5], xlv, 66-85, 1898.

motor. As long as the load on the dynamo was not varied the speed remained very constant. Greater constancy of speed was secured by operating the motor from storage batteries. The voltage furnished by the alternator could be controlled by slightly altering the strength of the field. For the determination of the frequency a chronograph was used. A kind of speed counter was connected to the shaft of the dynamo and a contact so arranged that in every ninety-seven revolutions of the dynamo armature a circuit was closed and a record made on the chronograph sheet. The chronograph was set up close to the rest of the apparatus and by means of a thread the pen could be raised for an instant from the sheet and so the exact time of making an adjustment could be readily noted. By interchanging the gear wheels the cylinder of the chronograph was made to run at about three and one-half times the customary speed. The distance between the checks indicating the seconds was so increased to over five and one-half centimeters.

A scale similar to that shown in fig. 1 was then constructed,



consisting of fine lines scratched on transparent celluloid and blackened with India ink. By means of this scale it was possible to read the chronograph sheet directly to fiftieths of a second and to estimate to five hundredths. However, in reading a chronograph sheet as exactly as this, certain precautions must be taken. First, the checks indicating the seconds should be sharp and distinct. Secondly, an error may arise if the chronograph does not run quite regularly. This can generally be remedied by properly adjusting the governor. By this method the fre-

quency could be quite accurately determined, to $1/10$ per cent or closer, if the sheet was read with sufficient care. It is to be noted that if sidereal seconds are recorded on the chronograph sheet they should be reduced to solar seconds, otherwise an error of $3/10$ per cent is introduced in the absolute value of the frequency and, therefore, of $6/10$ per cent in the value of self-inductance.

Apparatus.

Electrodynamometer.—A Rowland electro-dynamometer was used. The self-inductance of the fixed coils was $\cdot 0165$ henry, and of the hanging coil $\cdot 0007$ henry.

Resistances.—In the measurements of self-inductance with alternating currents, ordinary resistance boxes are of little or

no value owing to the electrostatic capacity of the doubly wound coils. Except in the case of a few determinations with Method 25, all the resistances used were made of a special German silver resistance wire, B. and S. gauge, Nos. 30 and 27. This wire was not doubled, but wound continuously in one layer on slates or pieces of micanite, each slate containing about 2000 ohms conveniently subdivided. The self-inductance and capacity of such resistances is entirely negligible. For fine adjustment a small resistance box was constructed differing from an ordinary box in that its coils were wound flat on thin pieces of micanite.

Coils and Condenser.—The coils whose inductance were measured were as follows:

P, external diameter 33.46^{cm}, internal diameter 23.8^{cm}, was made of about 1200 turns of No. 16, B. and S. gauge single cotton-covered copper wire. Self-inductance as determined, .5729 henry. Resistance, 36.3 ohms.

C. Same dimensions as P except depth. It consisted of 1747 turns of No. 22 B. and S. gauge single cotton-covered copper wire. Self-inductance found to be 1.3025 henry. Resistance, 78 ohms.

S. External diameter 23.5^{cm}, internal diameter 15^{cm}, depth about 3.5^{cm}. It consisted of 2082 turns of No. 22 B. and S. single cotton-covered copper wire. Resistance, about 69 ohms. Self-inductance found to be 1.0331 henrys.

Condenser.—A $\frac{1}{8}$ microfarad mica condenser.

Conditions of sensibility.—The deflection of an electro-dynamometer is proportional to the product of the currents flowing in the fixed and hanging coils multiplied by the cosine of the phase difference of the two currents. In most of these Rowland methods the adjustment consists in so altering non-inductive resistances in one or more branches of the bridge that there is a ninety degree phase difference between the currents in the fixed and hanging coils respectively. Evidently in order to secure maximum sensibility the currents through the dynamometer coils should be as heavy as possible, heating alone being the limit.

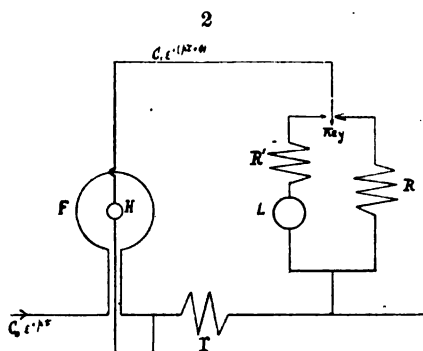
Sources of Error.—In work with alternating currents great care must be exercised that one part of the network does not exert an inductive action on another, e. g., that the coil whose inductance is being measured does not affect the hanging coil of the electro-dynamometer. Induction was carefully guarded against by the arrangement and tested for by means of reversing switches. The electrostatic capacity of doubly wound coils and resistances has already been mentioned as well as the precautions taken to avoid it. In the experiments here described all the connections were made as short as possible and no wires were twisted. Heating of the resistances was avoided as much

as possible and in the more accurate work the resistances of the several arms of the network were measured after adjustments on a Nalder standard "Post Office" box. All resistances are in International ohms.

Methods Used.

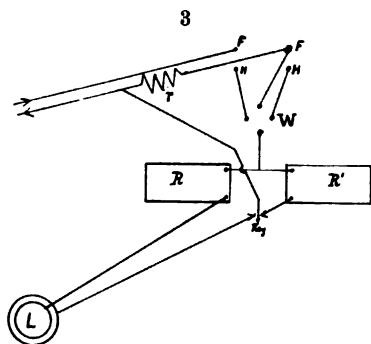
I.

Method 25.—The first method tried was that designated in Professor Rowland's article as number 25. It is an absolute method intended for the measurement of either self-induction



or capacity, the value of which depends upon the square of the current frequency. It was given a thorough test by Dr. T. D. Penniman,* except in so far as his method of measuring the frequency was rough compared with that used in this investigation, and he ascribes the lack of uniformity of his results chiefly to a want of

knowledge of the current period. It was therefore thought well to give the method a hasty trial in regard to the measurement of self-induction. In this method the hanging coil is shunted off the fixed coils circuit and the deflection with a non-inductive resistance in circuit with the hanging coil is made the same as that of an inductive resistance in circuit with the hanging coil. The method and connections are shown in figs. 2 and 3; F and H represent the fixed and hanging coils of the electro-dynamometer; R, R' and r, the total resistances of the three branches; L is the self-inductance of the coil to be measured, W is a reversing commutator. The formula for the method



as deduced by Dr. Penniman is,

$$p^2 L^2 = (R' - R)(R + r)$$

where p is equal to 2π multiplied by the current frequency.

* This Journal, viii, p. 85, 1899.

This method did not prove satisfactory for measuring self-inductance. With care it is possible to obtain values which do not differ among themselves by more than 1 per cent. One drawback to the method is its lack of sensibility, that is, it is not usually possible to adjust the resistances closer than one part in three hundred. Again, since the electro-dynamometer was very "dead beat" it required a certain small time to compare the deflections, to be sure not long, but enough for the current period to alter slightly unless special precautions were taken. A few determinations of the self-inductance of coils S and C are given. It will be noticed that the values are lower than those obtained later by a more accurate method. This is probably due to the use of ordinary resistance boxes possessing electrostatic capacity. This method was the first tried and is the only one in which such resistances were used.

TABLE I. Coil C.

Zero.	Deflection.	R.	R'.	r.	n.	L.
24.98	15.30	149.7	1513.7	4.017	57.567	1.266 henrys
"	15.49	"	1531.7	"	57.227	1.282 "
24.82	15.18	"	1518.7	"	57.453	1.271 "
"	15.11	"	1530.7	"	57.510	1.275 "
24.77	12.70	199.7	1241.7	"	57.453	1.276 "
24.73	12.62	"	1238.7	"	57.510	1.273 "
						Mean 1.274 "

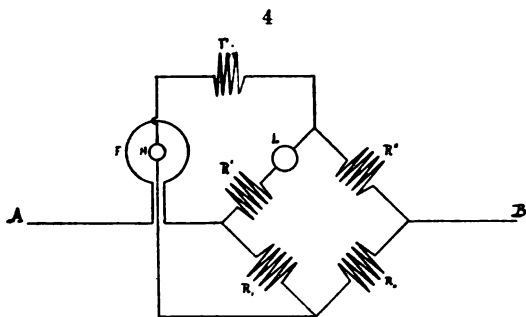
TABLE II. Coil S.

Zero.	Deflection.	r.	R.	R'	n (cycles).	L (henrys)
240.0	158.2	4.017	141.5	1300.7	63.885	1.023
"	158.5	"	"	1283.7	63.62	1.021
"	"	"	"	1283.7	63.329	1.020
239.2	301.0	"	"	1288.7	63.261	1.028
"	"	"	"	1281.7	"	1.025
239.0	134.2	"	191.5	1041.7	64.095	1.012
"	134.8	"	"	1038.7	63.955	1.013
238.7	345.8	"	"	1036.7	"	1.012
"	"	"	"	1038.7	"	1.013
249.0	121.3	"	241.5	920.7	64.095	1.014
"	"	"	"	922.7	"	1.015
239.1	129.9	"	291.5	850.7	64.167	1.009
"	"	"	"	"	64.095	1.010
239.7	"	"	491.5	836.7	64.23	1.025
						Mean 1.0171 henry

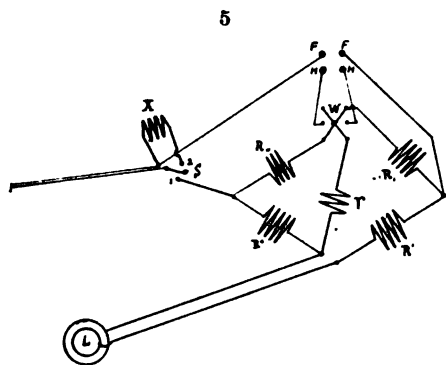
II.

Method 14.—The next method tested was that which in Professor Rowland's paper is number 14. It is an absolute method for measuring either self-inductance or capacity. It is a zero

deflection method depending upon adjusting the resistances until there is a ninety degree difference in phase between the currents flowing in the fixed and hanging coils of the electro-dynamometer. The method was devised and first used by Oberbeck,* later by Troje.† However, the frequency deter-



mination of both these investigators was quite crude and, as will be seen from the formula, the value of L or C varies as the square of the frequency. Diagrams of the method and connections are



given in figs. 4 and 5. As before, F and H represent the fixed and hanging coils of the electro-dynamometer; R , R'' , R' , R''' and r are the entire resistance of the several branches, L is the self-inductance of the coil to be measured, and l that of the hanging coil of the electro-dynamometer, W is a commutator for reversing the current through the hanging coil, S is a switch by means of which the current could be sent through a resistance X in value closely equal to the impedance of the network. The coil L , to avoid any possible effect on the rest of the network or hanging

coil of the electro-dynamometer, was placed some distance away usually on a level with the hanging and fixed coils and perpendicular to them.

If now an alternating electromotive force be applied to the terminals A and B , we may express the currents in the fixed and hanging coils of the electro-dynamometer by $C_0 e^{ipt}$ and $C_1 e^{i(pt+\phi)}$, p being equal to 2π times the frequency. By the application of Kirchhoff's laws to the Wheatstone bridge

* Wied. Ann., xvii, p. 816, 1882.

† Ibid., xvii, p. 501, 1892.

using "generalized resistances," we obtain as the ratio of the current in the battery arm to the current the bridge arm,

$$\frac{C_b}{C_s} \epsilon^{i\phi} = \frac{(r + ipl) (R_s + R + R' + R'' + ipL) (R_s + R') (R_s + R' + ipL)}{R_s R' - R_s R'' - ipLR''}$$

Multiplying both sides of this expression by C_s , rationalizing, and equating the real parts we obtain,

$$C_s \cos \phi = C_s \frac{[R_s R' - R_s R''] [r(R_s + R + R' + R'') - p^2 L l + [R' + R_s] [R_s + R'']]}{[R_s R' - R_s R'']^2 + p^2 L^2 R''^2}$$

$$C_s \frac{p^2 L l R_s (R_s + R + R' + R'') - p^2 L' r R_s - p^2 L' (R_s + R') R_s}{R_s R' - R_s R'' + p^2 L^2 R''^2}$$

This expression must be equal to zero since we adjust the bridge until $\phi = 90^\circ$, therefore $\cos \phi = 0$. Equating to zero and simplifying,

$$L' + L l \left\{ \frac{(R' + R_s) (R_s + R + R' + R'')}{R_s (r + R' + R_s)} \right\} = \frac{R' R_s - R_s R''}{p^2 R_s} \left\{ \frac{r(R_s + R + R' + R'') + (R' + R_s) (R' + R_s)}{r + R' + R_s} \right\}$$

This formula is somewhat simplified if R_s is chosen equal to R'' . However, for accurate work the equality must be exact. Since the self-inductance of the hanging coil of the Rowland electro-dynamometer is so small, only .0007 henry, the correction of L due to it is very small, in the case of coil C amounting to .0004 henry.

In using the method the numerical work involved in the calculation of L is rendered somewhat easier if we write the formula,

$$L + sLl = t$$

when very approximately, since l is so small,

$$L = t + \frac{S}{2} l$$

where

$$S = \frac{(R' + R_s) (R_s + R + R' + R'')}{r + R_s + R''}$$

$$\text{and, } t = \frac{1}{p^2} \left[R_s \frac{R'}{R_s} - R' \right] \left[R' + R_s + \frac{r(R_s + R'')}{r + R_s + R''} \right]$$

This method was found to be excellent. It is very sensitive and very accurate provided certain precautions are taken. Some little difficulty was experienced at first from the fact that the values of the self-inductance of a coil measured on any one day, although agreeing pretty well among themselves,

differed from those obtained at a different time. The cause of this variance proved to be the heating and consequent lack of knowledge of the resistances. In order to secure sensibility of the electro-dynamometer it was the custom to make the current through the fixed and hanging coils quite heavy. Sometimes the current through the fixed coils was nearly $\frac{1}{10}$ ampere. This was unnecessarily large, as with a current of $\frac{1}{30}$ ampere it is easily possible to adjust the resistance to one part in fifteen hundred or two thousand. If we wish to make exact measurements of inductance, the method requires an accurate knowledge of the resistances. To take a specific example, if in the first determination in Table IV we increase R or R'' by $1/20$ per cent, a change of $-1/3$ per cent is introduced in the value of L ; similarly changing R or R' by $1/20$ per cent we alter L by $+1/4$ per cent. In regard to r , L varies only as the first power. Fortunately these errors in L introduced by variation of the resistance are not all of the same sign, and since the current through r must of necessity be quite small (about $\frac{1}{100}$ ampere) the currents through $R + R$ and $R' + R'$ are nearly equal. Hence if we assume an increase of all the resistances of $1/20$ per cent, the value of L is increased by about one part in one thousand three hundred. Therefore, to obtain the best results with this method we must measure the resistances carefully and avoid much heatings. To avoid heating of the resistances the following plan of taking readings was adopted. The bridge was first adjusted, this being done by altering R' and R , until on reversing the current through the hanging coil of the electro-dynamometer there was zero deflection indicating a ninety degree phase difference between the fixed and suspended coils. By means of the switch S (vide fig. 5) the current was turned through the resistance X , made closely equal to the impedance of the network. This was done to avoid change in the frequency. After a considerable interval, sufficient to avoid the effect of any slight heating in the preliminary adjustment, the current was again switched through the network and R , remaining the same, R' readjusted to give zero deflection, the exact time of adjustment being noted in the chronograph sheet. This adjustment when made would usually hold good for several minutes. However, it was not usually necessary to run the current through the network longer than twenty or thirty seconds. This process was repeated a number of times with longer or shorter intervals and then the resistances R' and R , measured. The other arms of the bridge were measured once or twice during the evening; this time was chosen as being free from various disturbances. Generally for several successive observations the same value of R' would give zero deflection, R , remaining the same. The mean of the frequencies measured for the several observations was taken as being nearest correct.

If, however, R' had to be altered, the observations were regarded as separate and so worked out.

It was not the purpose of the authors to measure inductance to any great degree of accuracy, but to indicate the possibilities of the methods. Resistances were measured only to about two or three parts in ten thousand on the post office box, which had a considerable temperature correction. Still it will be seen that the determinations of L , except those of coil P , differ from the mean by less than 3/10 per cent.

The measurements of coil P were among the first made with this method, and the resistances were not measured with as much care as in the case of the other coils.

TABLE III.
Oct. 24, 1903.

R_s	R'	r	R_s	R'	n	L
103.75	103.67	425.06	900.76	870.9	65.644	.5722 henry
"	"	"	900.76	870.9	65.614	.5725 "
"	"	"	948.23	919.72	65.763	.5715 "
"	"	"	989.3	961.7	65.763	.5737 "
"	"	"	900.76	870.94	65.614	.5723 "
"	"	"	948.23	918.67	65.614	.5733 "
"	"	"	989.3	961.7	65.614	.5749 "
Mean						.57291 "

TABLE IV, Coil C.

Dec. 10, 1903.							
Temp	R_s	R'	r	R'	R'	n	L (henrys)
16° 3C.	99.907	99.78	968.8	1199.86	1088.6	63.288	1.3044

After the elapse of some minutes.

"	"	"	"	1199.86	1088.6	63.288	1.3044
---	---	---	---	---------	--------	--------	--------

Dec. 13, 1903.

15° 0	99.94	99.42	968.9	1200.47	1088.0	62.366	1.3055
"	"	"	"	"	"	62.446	1.3008
"	"	"	"	"	"	62.259	1.3047
"	"	"	"	"	"	62.206	1.3058

Mean 1.30257

TABLE V, Coil S.

Nov. 13, 1903.							
R_s	R'	r	R_s	R'	n	L (henrys)	
100.0	100.0	425.06	1815.5	1767.2	65.393	1.0309	
"	"	"	"	1766.67	65.393	1.0366	
"	"	"	1862.9	1815.5	65.688	1.0303	
"	"	"	1904.0	1856.96	66.091	1.0311	
"	"	"	1904.0	1856.96	65.763	1.0353	
Mean						1.0329	

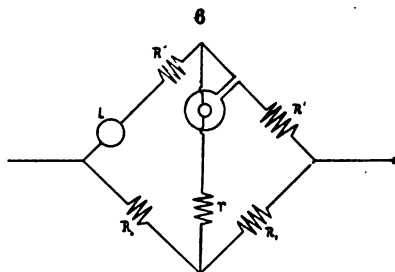
TABLE VI, Coil S.

May 13, 1904.

R_s	R'	r	R_s	R'	n	L
100.16	99.42	1020.2	1816.9	1734.0	78.121	1.0345 henrys
"	"	"	"	1734.5	78.303	1.0359 "
"	"	"	"	1760.6	61.797	1.0307 "
"	"	"	"	1734.5	78.278	1.0325 "
"	"	"	1905.3	1819.3	81.410	1.0330 "
"	"	"	"	1818.3	81.700	1.0365 "
"	"	"	"	1848.8	62.604	1.0354 "
"	"	"	1616.0	1529.6	76.456	1.0333 "
"	"	"	"	1528.3	76.068	1.0294 "
"	"	"	"	1530.1	76.428	1.0299 "
						Mean 1.02331 "

III.

Method 13.—Method 13 was next tried. This is also an absolute method for measuring either self-inductance or capacity. It is a zero deflection method depending on a ninety degree phase difference just as in method 14. In fact it differs from that method only in that the fixed coils of the electro-dynamometer are no longer in the battery arm of the bridge. The connections are shown in the diagram. Neglecting the self-inductance of the fixed and hanging coils of the electro-dynamometer, the formula for the method may be deduced as follows. Proceeding as before, we find the ratio of the current in the fixed and hanging coils



tions are shown in the diagram. Neglecting the self-inductance of the fixed and hanging coils of the electro-dynamometer, the formula for the method may be deduced as follows. Proceeding as before, we find the ratio of the current in the fixed and hanging coils

$$\frac{C_s \epsilon^{i(\phi_s - \phi_s)}}{C_s} = \frac{r(R_s + R_s) + R_s(R_s + R' + ipL)}{R'R_s - R_sR' - ipR_sL}$$

Rationalizing the fraction, and taking the real parts, we have for zero deflection;

$$p^2L^2 = \frac{\{R'R_s - R_sR'\} \{r(R_s + R_s) + R_s(R_s + R')\}}{R_s^2}$$

We should expect this method not to be as sensitive as Method 14, for the reason that we must in general have a smaller current in the fixed coils of the dynamometer. Moreover, since the formula is similar in character to that of Method 14, we would

look for the value of L to be affected in the same way by a slight heating of one or more of the resistances. {The formula for Method 14, neglecting hanging coil correction is

$$p^2 L^2 = \frac{[R_1 R'_1 - R'_1 R_2] [r(R'_1 + R_1 + R_2 + R'_2) + (R'_1 + R_2)(R'_2 + R_1)]}{R(r + R'_1 + R_2)}$$

The method was set up and some determinations made of the inductance of coil C. The method proved much less sensitive than Method 14, under comparable conditions only about one-half. By sensitive is meant the degree of accuracy to which it is possible to change the resistances, in securing adjustment.

It is to be noted that the formula as given neglects the self-inductance of the fixed and hanging coils of the electro-dynamometer. The exact formula is not difficult to work out, but the method is hardly sensitive enough to justify the trouble.

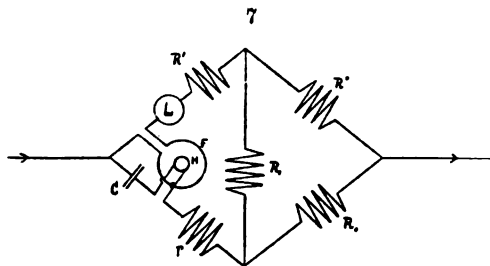
A few measurements of the inductance of coil C were made with some care. The values obtained were low compared with those previously obtained, as will be seen from the following example.

$$\begin{array}{lll} R_1 = 1201.7 \text{ ohms} & R'_1 = 1560.6 \text{ ohms} & r = 309.91 \text{ ohms} \\ R_2 = 99.89 \text{ " } & R'_2 = 133.33 \text{ " } & n = 69.153 \text{ " } \\ & L = 1.1483 \text{ henrys} & \end{array}$$

IV.

Methods 1, 2, 3, etc.—Attention was not turned to the first six methods given in Professor Rowland's paper, which are for the comparison of self-inductance with capacity. They are all zero deflection methods depending on a ninety degree phase difference. As will be seen from the formulæ, the value of $\frac{L}{C}$ is independent of the frequency. Two of these methods have already been used.

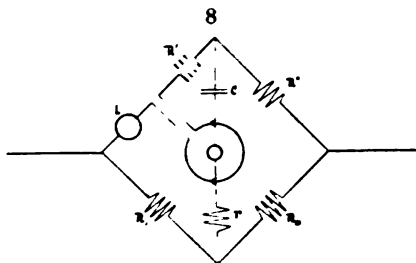
Method 6 was studied by Mr. Penniman but did not yield favorable results. Method 3 was employed by Mr. Potts in the course of some work on electric absorption, and was found very satisfactory. The diagrams and formulæ for the methods are as follows. The method of deducing the formulæ is the same as that followed in the preceding cases.



Method 1.—See fig. 7.

$$\frac{L}{C} = \frac{[r(R_1 + R') + R_2(r + R_2)] [R'(R_1 + R_2) + R'(R_1 + R')]}{(R_1 + R' + R_2)^2}$$

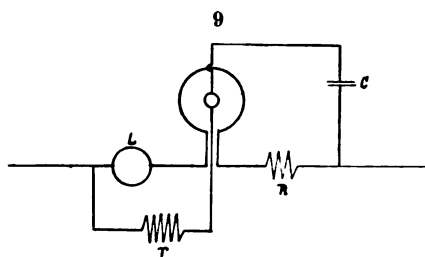
The trouble with this method was its lack of sensibility. Various values of resistances and coils were tried, but with the arrangement, which was as sensitive as possible, the resistances could not be adjusted closer than 1/5 per cent. This also when the maximum current was flowing through the network. It will be noted that the formula is quite similar to that of Method 14, so we should expect



the value of $\frac{L}{C}$ to be affected in the same way as was L by a slight change in one or more of the resistances. The values of the resistances which seemed to give the most sensitive arrangement when coil P was compared with a $\frac{1}{2}$ -microfarad mica condenser were,

$$\begin{aligned} R' &= 336 \text{ ohms} \\ R_1 &= 1200 \text{ ohms} \end{aligned}$$

$$\begin{aligned} R' &= 100 \text{ ohms} = R \\ r &= 3900 \text{ ohms} \end{aligned}$$



Method 2.—See fig. 8.

When $L = .570$ and $C = \frac{1}{2}$ -microfarad. The values of the resistances which seemed to give the most sensitive arrangement were,

$$R' = R_1 = 100 \text{ ohms}$$

$$R_2 = 1600 \text{ ohms}$$

$$R' = \text{about } 1600 \text{ ohms}$$

This method did not seem to be capable of adjustment much closer than 1 per cent even when the current through the network was .08 amp., which was much too large to avoid heating.

Method 3.—See fig. 9.

This is the simplest of the methods for determining $\frac{L}{C}$. The formula is

$$\frac{L}{C} = rR'.$$

As has already been stated, this method has been used with

success. The present writers set up the method and compared coil P with the $\frac{1}{2}$ -microfarad condenser. The method is very sensitive. With $r = 3070$ ohms and $R = 485$ ohms, a change of two ohms in r caused a change of 1^{mm} in the deflection of the electro-dynamometer. Determinations of the ratio $\frac{L}{C}$ were not made for the reason that if we wish accurate results it is necessary to measure the absorption resistance of the condenser. This should be done at each determination of $\frac{L}{C}$, as the absorption has been found to vary greatly both with the temperature and the frequency.

The diagrams and formulæ for Methods 4 and 5 are given: also the values of the resistances of the arms which seemed to give the most sensitive arrangement. As before, coil P, was compared with the $\frac{1}{2}$ -microfarad condenser.

Method 4.—See fig. 10.

$$\frac{L}{C} = \frac{\{R'(r + R_u) + R''(R' + R_u)\} \{R'(R' + R_u) + R''(R' + R'')\}}{R'R''}$$

As adjusted,

$$R_u = 88.54 \text{ ohms}$$

$$R' = 1021.8 \text{ ohms}$$

$$R'' = 99.5 \text{ "}$$

$$r = 492.0 \text{ "}$$

$$R_s = 317.5 \text{ "}$$

With $C = .086$ ampere, a change of 4.4 ohms in r is barely detectable and a change of ten ohms in R' produces only 2^{mm} deflection as measured on the scale of the electro-dynamometer.

Method 5.—See fig. 11.

$$\frac{L}{C} = \frac{[R_s(R' + R_u) + R_u(R' + R'')][R'(R' + R_u) + r(R' + R'')]}{(R' + R'')(R' + R_u)}$$

As adjusted,

$$R_s = 100 \text{ ohms}$$

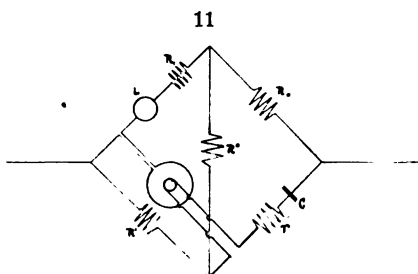
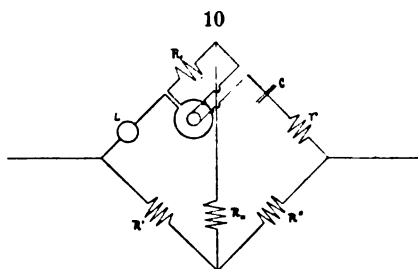
$$R' = 88.5 \text{ "}$$

$$R_u = 1041.5 \text{ "}$$

$$R_s = 317.5 \text{ "}$$

$$r = 1678.4 \text{ "}$$

This method is somewhat more sensitive than Method 4, however, it is not possible to adjust closer than one part in five hundred.



V.

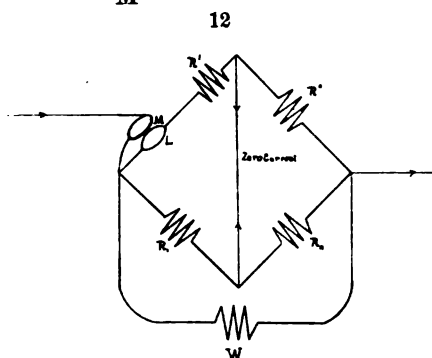
Methods 7, 8, 9, 10, 11, and 12.

Of the remaining zero-deflection methods which depend on a ninety degree phase difference, little needs to be said. Methods 7 and 8 are for determining $\frac{L}{C}$ but involve mutual inductance and are intended to be used with doubly wound coils. For accuracy greater than one per cent such coils are very undesirable on account of the electrostatic capacity, and should not be used. Methods 9 and 10 are for comparing mutual inductance with capacity. Method 12 was investigated by Mr. Penniman.

VI.

Methods 15-24.

The rest of the methods require at least two adjustments; first, the Wheatstone bridge must be balanced with direct currents, then adjustment made with alternating current so that the current through the bridge arm is zero. Of these methods, 15 and 16 are for comparing two inductances, two capacities or inductance with capacity. However, Method 15 requires after balancing the bridge with direct currents two simultaneous adjustments with alternating current; and Method 16 requires many resistances of known ratio. Method 17 is for the measurement of $\frac{L}{M}$, but as Professor Rowland points out: "It is



difficult to apply, as two resistances must be adjusted and the adjustment will only hold while the current period remains constant." These methods did not seem to be worthy of trial.

Method 18 is for the determination of $\frac{L}{M}$ where L and M belong to the same coil. This method is simpler than

most of the others and seemed rather more promising, so it was given a trial. The diagram of the method is shown in fig. 12.

The bridge is first balanced with direct currents giving

$$R'R_1 = R'R'.$$

Then with alternating current W is adjusted until there is zero current through the bridge arm, as shown by an electro-dynamometer or telephone. When this is the case the mutual inductance completely counterbalances the self-inductance, so that the currents and electromotive forces are in phase in each arm of the bridge. Representing current through R' by I' , etc.,

$$R, I = R'I' + ipLI' - ipM(I' + I + I_w)$$

also

$$R, I = R'I'$$

and

$$\frac{I'}{I_w} = \frac{W}{R' + R''}$$

$$\therefore \frac{pM(I' + I + I_w)}{I'} = pL$$

Hence

$$\frac{L}{M} = 1 + \frac{R'}{R} + \frac{R' + R''}{W}$$

The method was set up so that by means of switches the resistance W could be replaced by the battery, and the electro-dynamometer by the galvanometer. The method proved very unsatisfactory. Using the electro-dynamometer in the bridge arm, its coils being connected in series, W could not be adjusted closer than three per cent. Different values of the resistance were tried but the result was about the same. The electro-dynamometer was then replaced by a telephone. It was then possible to adjust to about two per cent but the noise of the dynamo interfered somewhat with the use of the telephone. The conclusion was that the method is not sufficiently sensitive to be of value.

Method 19 is also intended for the measurement of $\frac{L}{M}$ but involves the use of a doubly wound coil.

Methods 20 and 21 require a specially doubly wound inductance coil. They were not thought sufficiently promising to merit the construction of such a coil.

Method 22 is Carey Foster's method adapted to alternating currents. This method was rather thoroughly investigated by Heydweiller.*

Method 23 requires two simultaneous adjustments with alternating currents, and Method 24 is only of special use in comparing two doubly wound coils.

Summary.

With the exception of Methods 14, 3 and 25 the Rowland methods tested are of little value, their chief defect being a

* Wied. Ann., liii, p. 499, 1894.

lack of sensibility. Method 14, or more properly, the Oberdeck method, is without doubt the best method that we have for the absolute measurement of self-inductance in terms of resistance. It is easy to apply and if proper care be exercised results should not differ from the mean by more than 2/10 per cent. Greater accuracy than this is undoubtedly attainable and ought not to be a matter of any great difficulty, for in the work here described the frequency determination could have been improved and the resistances much more accurately measured. Method 25 is better than the Rayleigh method as ordinarily used, is very easy to work and has a very simple formula, involving little calculation. Its accuracy is probably limited to about one per cent. Method 3 for comparing self-inductance with capacity is very sensitive and was found by Dr. Potts to be very satisfactory.

Johns Hopkins University,
Baltimore, Md.

ART. X. — *Climatic Features in the Land Surface;*
by ALBRECHT PENCK.

THE surface of the land is composed of slopes which are for the most part gentle. Steep cliffs and overhanging forms are exceptional and insignificant features; where they occur, they are soon destroyed. Their fragments fall and slide and finally creep down; thus all cliffs and overhanging forms are transformed in the course of time into slopes and finally into long grades. It is important to see that this process can be accomplished simply by the force of gravity, helped by the action of weathering, but without the interference of water. The grading of the land surface is therefore a planetary process which will occur on every planet whose surface is liable to weathering as a result of changes of the surface temperature. The slopes formed by weathering are normal to the direction of those cliffs from which they originated, and if there was no stream or wave action, no glacial or wind action on the earth, the direction of slopes would be determined chiefly by the direction of the cliffs formed by earth movements, and we should observe in all slopes of the surface of the earth the directions of crustal and volcanic movements.

But the direction of the slopes on the land surface reveal other features, and a study of the processes going on on the land surface shows us that the origin of its slopes is above all connected with atmospheric action. Running water produces long and extensive slopes by its erosive and constructive force; it is enabled to transform slopes caused by crustal movements into others which show a perfect adjustment to the material of the earth's crust; and finally it wears the land down to gently sloping surfaces of the highest resistance. Running water also deposits material in the form of gently sloping plains, which extend very far. The action of running water is therefore both a degrading and an aggrading one, and the grades which it forms show a systematic arrangement; they slope down in the direction in which the water moves, mostly towards the sea; on one quarter of the land surface, however, towards the interior of the continent, where the running water is evaporated; and exceptionally in several regions composed of soluble rocks, to those points where water enters the rock to follow there a subterranean course. The latter case is a rather unusual one; it is connected with the very remarkable forms of the Karst phenomenon, which, however, are only of limited extent.

Glacial action also produces slopes, either due to erosion or to accumulation, but these slopes do not show such a systematic

arrangement as the grades of fluvial origin. Glacial action does not impose on the land the continuity of its surface slopes as running water does; it produces irregularities in its bed which not only show continuous slopes but often opposite and reversed slopes. Wind also produces slopes, but their arrangement is still more irregular than those of a glacier bed. There is a sharp limit between the regions of glacial erosion and of glacial deposition; the forms of eolian erosion and eolian deposition also occur in close proximity; wind does not transport so continually nor so far as running water and glaciers do; its action is more brief and unsteady. Thus, the arrangement of the slopes of the land surface permits us to recognize fluvial, glacial and eolian forms.

Now the action of running water and of glaciers and the display of eolian forces depend on climate; rivers exist only where a part of the rain runs off superficially on the land; their morphological action depends, therefore, on the amount of run-off, which is consequently a geomorphological factor of great importance. Glaciers are formed only where the amount of snowy precipitation surpasses that amount which can be melted away by the action of the sun. Wind action finally becomes very visible, and is exclusively performed where neither water nor ice action occur. We see, therefore, that the differences between precipitation and evaporation on one side and between snowfall and ablation on the other, determine the surface features of the land, and hence we can recognize in the surface features of the land certain features of its climate in the same way as in its covering with vegetation.

The display of river action does not depend alone on climatic conditions. River movement is only possible where there is a slope on which the rivers can flow. Only their existence is due to climate, while the display of their force depends on differences of elevation, and their action consists in the degradation of existing heights. Glaciers do not necessarily presuppose elevations; they can be formed also on low grounds, if the climatic conditions of their formation are given. If more snow falls on a plain than can be melted away, it accumulates and will finally form an ice-cap which radiates from the plain; if here the accumulation reaches a great thickness, it can then overcome finally by its surface slope existing inequalities of its bed, as is clearly shown by the glaciation of North America during the Great Ice Age, which partly radiated from the low grounds west of Hudson Bay and overflowed in the east the mountains of New England. Whilst river action consists in the destruction of given inequalities of the earth's surface, glacier action can create new inequalities by the erosion of the central floor of an ice-cap formed at a low level and the deposi-

tion of the eroded material in higher levels around this center. The same can be said of eolian action. Wind can blow sand and dust from lower levels to higher ones, and if its action were long continued, it could lower the surface of vast tracts of land and raise the surface of others; the lowered surfaces could lie below the raised ones.

In order to understand more thoroughly the difference of river action on the one hand and of glacial and wind action on the other, let us consider their probable final results. In the course of time the rivers will totally degrade the continents to vast penepains and will extend them seaward by the accumulation of river plains; then they will have no action. A polar ice-cap will attack its floor if the slope of its surface is greater than the reversed slopes of its floor, and around this eroded area accumulation will go on. The difference of height between the central eroded area and the peripheral belt of deposition will be theoretically the larger the greater the thickness of the ice-cap, and it is theoretically possible that a very thick and moving polar ice-cap could finally excavate a deep basin in the polar region which would be surrounded by a high morainic belt. These processes would not only be accomplished on the land, but the ice-cap could also act on those parts of the sea-bottom which are not deep enough to make the ice float; and the morainic belt could therefore be accumulated as well on the land as on the bottom of the sea. But where the bottom of the sea becomes too deep, the ice-cap would break into pieces which would float away as icebergs and distribute the morainic material over vast areas of the sea-bottom. Let us assume that wind action operates unhindered by vegetation and the action of running water. Then the constant trade-winds would continually carry with them sand and dust which were accumulated in an equatorial belt, where the trade winds cease, and this action would be continued as long as the area eroded by the wind were not invaded by the sea. It could be eroded beneath sea-level as long as there were coast regions protecting it as natural levees against the waters of the ocean. Wind action does not necessarily stop at sea-level; the depressed areas of the land clearly show us that it is continued farther down. If, however, those natural levees are destroyed, vast regions denuded by wind action below the sea-level would suddenly be inundated and converted into seas. The material transported by the wind would be deposited not only on the land, but also in the neighboring seas, and an increase of the equatorial land area would be the consequence of continued wind action. Thus, by mere eolian activity, the distribution of water and land could be altered.

The effects of polar ice-caps and continual wind action would

consist in the movement of material from higher latitudes into lower ones, and the areas of erosion and deposition would show a zonal arrangement, whilst running water transports from higher regions to lower ones, and the corresponding areas of its action are controlled by the existing distribution of water and land. Glaciers and winds accomplish an important transportation of material from lower to higher positions. What we see in river action consists only of a downward transportation, and it generally ceases at sea-level; it can only be exercised below it in countries which extend for other reasons below this level, as for example, in the border regions north of the Caspian sea; whilst glaciers and winds could make vast depressions of the land beneath the sea-level.

These differences between visible river action on the one hand and glacial action on the other seem to be at first sight very strange, but a closer inspection shows that when speaking of river action we generally have in mind the processes which go on above the level of the river. We generally do not think of the processes performed in the river bed itself, for they are hidden under the water. But the study of river beds reveals that here much material is carried upwards and that the depth of the rivers is not at all limited by the sea-level. All river beds which reach the sea lie below the level of the sea near their mouths, and their bottoms extend the deeper and the farther below the sea-level the greater their volume. On the other hand, if we speak of glacial or wind action we have always in mind the processes going on in the beds of these moving fluids. These beds are of far larger extent than those of rivers, and therefore the action performed in them is far more conspicuous. The action of rivers in their beds gives origin to all those subærial processes which widen the vertical trench of a river into a valley and produce slopes towards the river. These subærial processes are the more important for the development of the earth's surface-features; they perform what we usually call river action, but they are not controlled by the movement of water, and belong to that class of phenomena which are dependent on the action of gravity.

The actual surface features of the land differ from those which are produced by continuous river, glacial and wind action. The land is not leveled down to a peneplain, no mountainous moraines are formed around vast depressions, and there is no equatorial belt of wind deposition between regions where deflation produced lowlands. We meet with elevations which are still in the state of being degraded and which are not made by glacial or eolian accumulation. The existence of those elevations reveals the existence of forces which counteract the atmospheric agencies, and which have

counteracted them the more, the greater the difference between the actual distribution of heights and the ideal ultimate effect of those agencies. In countries with dominant river action the existing elevations are differences between the effects of earth movements and the consequent degradation by river action. Their height is therefore determined by the intensity of crustal movement and by the time that has since elapsed. There are young mountains, attacked only along certain lines by water, which has only made an approach toward destroying the fortress; there are mature mountains which have already lost their unstable annexes and are formed by rocks of greatest resistance; there are old mountains degraded as far as possible, no longer forming elevations.

Young, mature and old mountains show very different structures, and we cannot, therefore, connect the idea of a certain class of crustal movement with mountain-making. Mountains are caused by all crustal and volcanic movements which are directed upward, either totally or as a component. But whatever the character of these movements is and however complicated they may be, they only exceptionally interrupt the slopes of fluvial degradation. This is shown by the facts that even in the regions of most recent elevations the continuity of the fluvial slopes or grades is only exceptionally interrupted, and nearly all of these interruptions occur in volcanic regions, where sudden outbursts take place. The intensity of crustal movement, therefore, is not so great that it can disturb the continuity of fluvial slopes; crustal movement can disturb a former arrangement of slopes, it can produce new slopes, but by their erosion and accumulation rivers maintain the continuity of slopes.

In desert regions crustal movements are able to interrupt slopes, for they are not counteracted by running water. It is in the deserts of the Far West where we see the best samples of recent faults; they cut through alluvial fans and form well-marked steps in regions of deposition and erosion. It is also in the deserts where we meet with such an arrangement of mountains that closed basins are formed. These closed basins came into existence because the grading river action was absent, and though formed by crustal movement, they are also climatic features of the earth's surface, for they are only produced under certain climatic conditions, namely, in regions where the amount of evaporation surpasses that of precipitation.

We see on the earth's surface not only the features of the present climate but also those of a past climate. Very extended areas, formerly covered by ice, are now exposed to river action. The basins formed by the meeting of normal slopes and those reversed slopes which originated under the ice, are filled with

water and form lakes; the river action has not reached a normal slope; waterfalls interrupt their courses. These lakes and waterfalls are indications of extreme youth of river action over large areas, and at the same time they are as significant morphological evidences of a recent climatic change as moraines and rock striations are in the geological sense. In mountain regions, as for example in the Alps, the lakes occupy valleys which have the arrangement of river valleys; they are subordinate to an older topography, formed by fluvial action, and we can recognize in the valleys of the Alps not only one climatic change, but a succession of those changes. In the lowlands of the north, however, it is nearly impossible to trace the features of an older topography under the glacial one. This, however, does not show those signs of antiquity which we might expect to find in regions of continual glaciation. Hence we must infer that the glacial features of other northern lowlands are also superposed on an older topography which has been destroyed in its characteristic features. We see on the border regions of the old glaciations moraines which have totally lost their morainic forms, and already possess the surface features of a mature fluvial topography. These surface features have long ago led to the conclusion that we have to deal here with older moraines, which indicate an older climatic change. Thus regions of river degradation indicate climatic change by their composition as well as glaciated regions indicate such change by their forms.

We meet with proofs of climatic changes also in desert regions. Investigations of American geologists, especially of Gilbert and Russell, have shown that the region of Great Salt Lake was once occupied by a far larger freshwater lake, the shore lines of which can be easily followed and the outlet of which can be recognized in a side valley of Snake river. We can trace in the Sahara very extended river valleys from the Highland of Ahaggar down to the region of the south Algerian Shotts. These valleys cannot be compared with those short wadies in which the water of cloudbursts rushes down. They indicate a former moister climate; the desert with its surface features extends here over a region of former water action in the same way as, farther north, river action is now displayed on a surface formerly covered by glaciers.

In the interior of two continents we finally meet with surface features which might be taken for morphological indications of a change of desert climate into a moister one. Three large lake basins interrupt the general grades of the head waters of the principal African rivers. In the region of the Zambesi river we find the very deep Lake Nyanza, in the catchment basin of the Congo the likewise deep lake Tanganyika, and

along the upper branches of the Nile the Victoria Nyanza. There are good evidences that the two first named lakes occupy depressions formed by crustal movement. Now we have seen that generally crustal movements, however profound they may be, do not interrupt the formation of slopes of degradation. Why did such interruption occur in central Africa? In order to give an answer, let us consider how the formation of isolated basins by crustal movement is hindered in the regions of fluvial drainage. A tract of land, sinking down, is filled up by sediment during its subsidence; thus the rivers maintain their slopes and the formation of closed basins is counteracted. Elevations occurring in river basins are often cut through by rivers during their elevation, and then they will not transform neighboring regions into closed basins. The formation of those basins by crustal movement will occur only when the rivers in the disturbed regions are too feeble to fill up the sinking regions and to cut through the rising chasms. The central African great lakes are located in the neighborhood of insignificant river action. East of them extend the dry plateaus of German East Africa. Here crustal movement has produced many closed basins called Gräben (tectonic troughs) by Suess. Many of these Gräben are empty, or filled only at their bottoms with soda-lakes; others are nearly filled, as for example, Lake Rudolph. A slight climatic change would fill the basin of this lake so that its waters would overflow in wet years. This is the case with Lake Tanganyika. Its outlet, the Lukuga, flows only in wet years; in dry years the great lake is without outlet. A stronger climatic change would transform Lake Rudolph into a normal freshwater lake with permanent outflow. This type of lake is represented in the neighborhood by the Victoria Nyanza, by the Albert and Albert Edward Nyanza, and farther south by Lake Nyassa. We can understand best the existence of the large freshwater lakes of east equatorial Africa by assuming that their water drowns basins formed in a dry climate, such as prevails farther east. It is very significant that these great lakes occur in a region of transition between the dry and the wet tropical climate, a region which would be affected very much by climatic changes. The same is true for Lake Baikal in eastern Siberia. It belongs to a zone of great inland lakes at the northern border region of the central Asiatic deserts. Three of these lakes have salt water; two of them are so large that they are called erroneously seas, namely Lake Caspian and Lake Aral; the third is the shallow lake Balkash. An increase of precipitation over Russia would cause a raising of the level of Lake Caspian and an extension of its surface, and if on this larger surface evaporation would not balance the increased

inflow, and establish thus a new equilibrium, then the lake will overflow in the Manich valley and would be changed in the course of time into a freshwater lake. On the other hand, if the desert region of Mongolia should extend, the principal affluent of Lake Baikal would become smaller, and a moment would arrive when the quantity of water running into Lake Baikal would be totally balanced by the evaporation going on there. Then this lake would lose its outlet, and the salts brought by its affluent would gather in its basin, and it would be transformed into a salt lake. Such rather light climatic changes would transform the salt lakes of the northern border regions of the central Asiatic deserts into freshwater lakes, or the large freshwater lake into a salt lake. We can understand best the existence of these lakes by the working hypothesis that their basins were formed originally in a dry climate, where river action could not neutralize transformation by crustal movement, and that they thence were more or less filled with water, according to the actual climate of their region. In this way we are disposed to recognize also in the great freshwater lakes in the interior of some continents morphological witnesses of climatic changes.

If we now look over the whole set of evidence, we see morphological traces of glacial action in countries which are now drained and shaped by running water, and recognize in mountain chains, as for example the Alps, traces of river action preceding this glacial action. We follow traces of extended river action into the desert, and we find forms which were probably produced in a dry climate, with no run-off, in regions which are now subject to river action. The climatic features of the land surface indicate that climatic changes are not only in one direction; we cannot say that the climate of the land is becoming dryer and dryer, or less and less glacial; they reveal continued climatic oscillations. These climatic oscillations are different in the different zones of the earth. We have to deal with oscillations between glacial and pluvial climate, and with oscillations between pluvial and desert climate. It is now the question, how these different oscillations were connected with one another, if there is a contemporaneity between them; and which changes were contemporaneous, those of glacial to pluvial climate with those of pluvial to desert climate, or *vice versa*. The evaporation of the deserts of the Far West has given one answer: it was there shown that the glaciers existed at the same time that the climate was moister. From this we can infer that one of the climatic oscillations indicated by the surface features of the earth consisted in a movement of the climatic zones from the pole towards the equator and back again. If this inference is right, we must find on the equatorial belt of

the great desert regions of the world traces of an old desert climate, where now a pluvial climate dominates. It is possible that the great central African lakes point in this direction; perhaps Lake Titicaca indicates by its content of rather fresh water that once the deserts of South America extended farther towards the equator, and perhaps the lakes of the plateau of Mexico point to the same relation with the deserts of North America, whilst Lake Baikal would indicate an opposite movement of the climatic zones from the equator towards the poles, which cannot have been contemporaneous.

There is one fact known from the Arctic regions which is in harmony with a migration of the climatic zones of the earth. Neither the American expeditions which have explored the neighborhood of Smith Sound, nor the Norwegian expedition which studied the archipelago lying farther west, succeeded in finding the traces of a former greater extent of the glaciers, which are so abundant farther south. At first sight this fact appears rather strange, but it can be understood in connection with the others. It shows that during the glacial period glacial conditions did not extend farther towards the pole into those regions where now the Arctic climate, on account of its dryness, is not very favorable to the formation of glaciers. The great glaciations of the northern hemisphere were not extensions of a polar ice-cap; they were confined to the vicinity of the Arctic circle, and they surrounded, as far as we can see, a region of an Arctic desert climate similar to the existing one. This fact would be consistent with an equatorial movement of the climatic zones of the earth.

If there are oscillations in the situation of the climatic belts of the earth, it must be asked if they are connected with the disappearance of existing climatic zones and the appearance of new ones. For this reason the equatorial and polar regions attract particular interest; it can be imagined that in times of an equatorial movement of the climatic belts some features of the equatorial climate would totally disappear, and new climatic conditions could come into existence in the polar regions. The reverse would occur in times of a polar movement of the climatic zones. There is also much interest in the study of all border regions of climatic belts, for every movement of climatic zones of the earth would here produce changes.

The very extended border region of the glacial and the pluvial climate has afforded a splendid occasion for the study of past climatic changes; the climatic history of the great Ice Age could here be determined by a careful study of the corresponding deposits, and newer researches have utilized to great advantage the glacial forms in determining the glacial climate. The forms of the earth's surface indicate climatic changes also

in other regions of the earth, and further research will help us to establish the general rule of all their climatic oscillations, and we shall understand them the better the greater our knowledge of the surface forms.

The forms of the earth's surface are very complex things. In the beginning of geological research it was generally maintained that every rock had its peculiar forms, and still to-day some text-books contain pictures of granite or sandstone mountains. Later, it was believed that every kind of structure of the earth's crust assumed its own surface features, and structural geology was regarded as the very content of geomorphology. Later still was recognized the importance of the different exterior processes which shape the earth's surface, and there are still many differences of opinion as to their effects. It is only recently that the full importance of time has been observed for the development of surface features. After having seen how different the forms are which come into existence in a natural sequence under the control of a certain process, as shown by the geographical cycle, we can fully appreciate the differences of fluvial, glacial and desert forms, and we shall have thus gained the possibility of such a close examination of forms that we can read their history.

This study of erosional forms can be supplemented by that of corresponding deposits. We now easily separate river deposits from moraines, which in the beginning of scientific research have been taken for the results of large floods. It is also possible now to distinguish the deposits of different phases of a geographical cycle from one another, and the variegated or impoverished composition of gravel deposits allows conclusions as to the surface features which prevailed during their formation. We do not doubt that continued observations of desert deposits will result in the establishment of sharp distinctions between them and fluvial deposits, though it is not easy to distinguish between deposits of young rivers of a pluvial climate and those of mature rivers of a desert climate. Thus the study of deposits may afford us a crucial test as to the result of our study of forms.

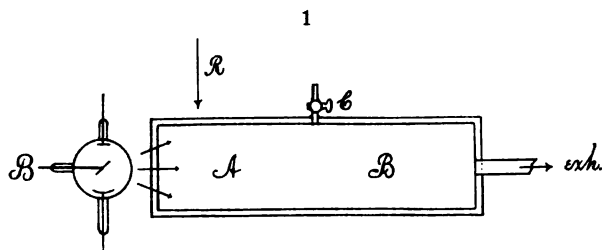
Forms are always in the way of evolution; where destruction prevails on the land surface the existing forms are always in process of destruction; only where they are buried under new deposits are they conserved. The surface of every layer deposited on the land has been an old land surface. Thus the study of deposits also reveal forms of the past, and if we are accustomed to interpret the meaning of forms and deposits, we can read far older climatic conditions in deposits than are exhibited in the existing surface features of the land.

ART. XI.—*Preliminary Results with an Objective Method of Showing Distribution of Nuclei Produced by the X-rays, for Instance; by C. BARUS.*

[The present research was carried out experimentally by Robinson Pierce, Jr., and myself, and I would gladly associate his name with mine at the head of this article, did he permit it.]

1. *Introductory.*—By passing the X-rays into one end of a long rectangular (virtually tubular) condensation chamber and observing the effect produced after successive different intervals of time by the condensation method, evidence with a possible bearing on the origin of these nuclei was obtained. The coronas are distorted and at first occur on the bulb side of the apparatus only. The distribution of nuclei is inferred from the form of the corona.

The experiments described were all made with *strictly dust-free* saturated moist air, as both the method of precipitation



and of filtration were applied prior to each experiment, and the exhaustion carried to a higher degree in the purifications than in the measurement. Furthermore as the exhaustions necessitated the use of short lengths of rubber tubing ($1/2$, $3/4$, and 1 inch in bore in the different cases), the amount of cooling obtained does not directly correspond with the pressure difference, δp , owing to the resistance of the tube to the flow of air. The data, δp , each refer to a given type of apparatus but are satisfactory as relations, so long as this is not changed. Furthermore the δp was so adjusted as to entrap all X-ray nuclei, to the exclusion of the normal, quasi-molecular nuclei of dust-free air.

2. *Apparatus.*—The method was purposely reduced to extreme simplicity and the apparatus is shown in the annexed diagram. *AB* is the long rectangular condensation chamber of wood impregnated with resinous cement. The front and rear faces are plate glass through which the coronas may be observed. The other sides are lined within with thick cotton cloth, kept wet, and there is a layer of water at the bottom to

insure complete saturation of air. *C* is a stopcock leading to an efficient filter (not shown). Supersaturation is produced by sudden exhaustion at the B-end of the apparatus, while the A-end receives the radiation from the X-ray bulb *B'*. A large vacuum chamber was placed in connection with the exhaust pipe shown, through a wide stopcock, the details of which need not be explained. The X-rays used were not very penetrating, and were obtained from a soft bulb actuated by a small induction coil (4" spark) and 3-5 storage cells. Two filters of solidly packed cotton were used, one 7 inches and the other 16 inches long. They were about equally efficient.

3. *Vertical radiation at one end of the trough, entering through wood.*—In the preliminary experiments the bulb was placed so as to radiate into the trough in the position shown at *R*, and kept in action 5 min. The effect was then observed by condensation at the pressure difference $\delta p = 17^{\text{cm}}$. Two results were noted: in the first place while the coronas obtained with the X-rays in bulky apparatus are usually of the smaller or normal type, the coronas seen in this shallow apparatus were often enormous, transcending the middle g-b-p corona (nucleation, $n = 100,000$ per cub. cm.). Even after two or three subsequent exhaustions, filtered air being added prior to each, large coronas were still in evidence.

In the second place, the coronas, and hence the nuclei, were observed chiefly on the A-side of the apparatus, under the bulb. Fearing that there might be some direct effect due to induced high potentials, the X-ray bulb was raised 10 and 20^{cm} above the trough, with results naturally smaller in magnitude but of the same kind. The following data may be given:

TABLE 1.—Number of nuclei, n , in thousands per cm^3 . $\delta p = 17^{\text{cm}}$. Temp. about 20°. angular aperture $\phi = s/30$.

Time of radiation	Bulb near trough (2 ^{cm})						Bulb 10 ^{cm} above trough				Bulb 20 ^{cm} above trough	
	5 min.		5 min.		5 min.		6 min.		5 min.		6 min.	
	<i>s</i>	<i>n</i>	<i>s</i>	<i>n</i>	<i>s</i>	<i>n</i>	<i>s</i>	<i>n</i>	<i>s</i>	<i>n</i>	<i>s</i>	<i>n</i>
Coronas on 1st exhaustion	*	—	*	—	*	—	3.9	20.5	3.5	15	2.7	6.6
“ “ 2d	—	—	—	—	6.5	100	2.7	6.6	2.7	6.6	1.9	2.2
“ “ 3d	—	—	—	—	5.9	68	—	—	—	—	—	—

* Immense but too diffuse for measurement.

In all cases the first coronas were accompanied by dense rain and fogs frequently in horizontal strata, so that sharp measurements of aperture are generally out of the question. Moreover the first condensation is accompanied by turbulent displacement of fog-particles, and the contents of the receiver are thoroughly stirred up. After filling with filtered air and

exhausting again, the coronas are therefore nearly uniform and alike on both sides. In the above table the nucleation produced decreases about as the inverse square of distance.

4. *Axial radiation entering one end of trough.*—Seeing that it is possible to retain the nuclei on one side of the trough, subsequent experiments were conducted with the X-ray bulb placed as shown in the figure. Moreover a smaller interval of radiation was selected, to more and more fully exclude the displacement of nuclei by diffusion. The angular diameters ($s/30$) of the coronas were measured with two gonimeters, one on each side (A and B) of the trough, the distance of the coronal centers from the bulb being about 20^{cm} and 47^{cm}, respectively. The following table summarizes the results obtained, remembering that all initial coronas are coarse and blurred and accompanied by copious rain and fog, so that the diameters must be estimated.

TABLE 2.—Number of nuclei in thousands per cm³. $\delta p = 17^{\text{cm}}$; angular diameter $\phi = s/30$.

Time of radiation	2.5 min.				3.5 min.				2 min.				2 min.			
	A-side		B-side		A-side		B-side		A-side		B-side		A-side		B-side	
	s	n	s	n	s	n	s	n	s	n	s	n	s	n	s	n
Corona on 1st exhaustion	4.5	32	2.2	3.3	4.5	32	2.2	3.3	4.0	22	2.0	2.5	2.5	5.2	0	0
" " 2d "	—	—	—	—	3.2	11	3.0	9.3	—	—	—	—	—	—	—	—

The second coronas are obtained after refilling with filtered air and it is noteworthy that after the rains of the foggy first coronas fall out (which they do rapidly), there are abundant nuclei left for the next corona. As stated, the nuclei are now uniformly distributed, and the coronas persistent, while in the first exhaustion, apparently, certain larger particles captured all the moisture and removed it in a rainy precipitate.

It is to be observed moreover that the nucleations on the A and the B sides in these cases are on the average as 9:1 or in a larger ratio, while the ratio of distances is below 1:2, because the absorption of the wood is equivalent to a removal of the bulb. Hence the density of distribution falls off faster than the inverse cube. The contrast is even greater, because in the 2 or 3 minutes of radiation some nucleation must arrive on the B-side by convection and diffusion.

We were originally of the opinion that there is marked absorption of the nucleating power of X-rays, by the successive vertical layers of air from left to right, but it is best not to prejudice the case here.

5. *Continued for larger pressure differences.*—Several questions now present themselves for immediate decision:

viz., whether all the X-ray nuclei have been caught and in how far the exhaustions are below the point of spontaneous condensation of moist air. Accordingly larger pressure differences were applied. Table 3 gives a few examples.

TABLE 3.—Nucleations n in thousands per cm^3 . Time of exposure to X-rays, 8.5 min. Angular aperture $\phi = s/30$.

$\delta p =$	17 ^{cm}		21 ^{cm}		31 ^{cm}	
Side	A	B	A	B	A	B
$s =$	4.6	1.8	3.9	2.1	2.8	2.5
$10^{-3}n =$	35	1.9	27	3.5	11	7.8
Ratio	18:1		7.7:1		1.4:1	

Hence above $\delta p = 21^{\text{cm}}$ for this apparatus, nuclei show themselves on both sides and the question arises to what extent the normal air nuclei or ions have been captured. At $\delta p = 31^{\text{cm}}$, the fog particles condensed on X-ray nuclei probably drop out at once and the persistent corona observed is precipitated on the normal or inseparable air nuclei stated.

6. *Spontaneous condensation in moist air in the absence of X-ray nuclei.*—With the object of finding the pressure difference of exhaustion, δp , corresponding to the lower limit of spontaneous condensation of moist air without foreign nuclei, experiments were first tried with a cock $3/4$ inch in bore, in the exhaustion tube. The results were identical on the A and the B sides, as follows:

TABLE 4.—Spontaneous condensation in saturated air. Angular aperture $\phi = s/30$.

	$\delta p =$	24 ^{cm}	31 ^{cm}
	$s =$	2.2	2.7
Repeated,	$s =$	2.4	3.2
“	$s =$	2.1	—
Do., large filter,	$s =$	2.2	3.5
Do.	$s =$	1.9	—
Air over nights,	$s =$	2.0	—
Mean	$\left\{ \begin{array}{l} s = \\ n = \end{array} \right.$	$\left\{ \begin{array}{l} 2.1 \\ 3,500 \end{array} \right.$	$\left\{ \begin{array}{l} 3.1 \\ 15,500 \end{array} \right.$
	$\delta p = 22^{\text{cm}}, n = 0$		

This indicates that at a pressure difference of about $\delta p = 22^{\text{cm}}$ for the given apparatus and dust-free moist air, spontaneous condensation with vanishing coronas begins, and that thereafter the coronas increase regularly.

In corroboration with the preceding, similar experiments were tried with an instantaneous valve, opening with a hammer, and having a clear bore of over one inch. The results shown in table 5 were identical on both sides but unexpectedly

irregular. Alternation of large and small coronas in dust-free air, such as are here imperfectly shown, may be kept up indefinitely if strictly identical conditions are retained. Effectively, the large fog particles emit more nuclei, the smaller fewer nuclei for the next condensation in order, everything else remaining the same. The importance of these oscillations about the mean aperture, whether the emission is ionized or not, cannot be called in question, as I shall show elsewhere.

TABLE 5.—Spontaneous condensation of saturated air. Angular diameter $\phi = s/30$.

Press. diff., $\delta p =$	19 ^{cm}	19.4 ^{cm}	21.4 ^{cm}	24 ^{cm}
Repeated, $s =$	2.3	3.4	3.3	4.4
“ $s =$	0	2.1	2.0	2.5
“ $s =$	0	0	3.0	4.3
“ $s =$	0	0	2.0	2.5
“ $s =$	—	0	3.5	3.3
“ $s =$	—	—	2.2	3.3
Mean $\left\{ \begin{array}{l} s = \\ n = \end{array} \right.$	0	0	2.7	3.6
	0	0	7,600	21,000
	$\delta p < 20^{\text{cm}}, n = 0$			

For $\delta p = 19.4$ and below, therefore, no nuclei appeared after thorough cleaning. For $\delta p = 20^{\text{cm}}$ and above, i. e., at a somewhat lower pressure difference than before in consequence of more rapid exhaustion, spontaneous condensation begins. The large coronas are blurred.

Hence in neither case will spontaneous air nuclei be caught at $\delta p = 17^{\text{cm}}$, in the given apparatus.

7. *Possibility of producing nuclei by very sudden intense exhaustion.*—This condensation of moist air in the absence of foreign nuclei is usually considered due to the spontaneous ionization of the air, the available nuclei increasing in abundance, as with increasing pressure differences the sizes of captured nuclei are smaller, until the air molecule itself is approached. It follows then that the normal dust-free air always contains unstable systems.

Hence the question may well be asked, whether very sudden and intense exhaustion may not itself possibly be productive of nuclei. Thus if an unstable molecular configuration is just about to break down, it is conceivable that the tendency to break-down is accentuated by the violent treatment in question.

We made some experiments on this subject,* using a pres-

* Investigations on the spontaneous condensation in moist air were first suggested by C. Barus, in Bull. U. S. Weather Bureau, No. 12, 1893, pp. 11-14, 48. They have since been fully treated in the masterly work of C. T. R. Wilson, Trans. Royal Soc. Lond., vol. 189, pp. 265-307, 1897; *ibid.*, vol. 192, pp. 403-453, 1899.

sure difference $\delta p > 30^{\text{cm}}$, by placing a gold leaf electrometer, properly insulated, in the condensation chamber. The loss of charge in damp air is at first surprisingly small; nevertheless the experiments are very difficult and we were unable to come to a conclusion. A decision will probably be reached by aid of the oscillating coronas mentioned in § 6.

8. *Successively increasing times of exposure to X-radiation.*—After this digression experiments were resumed with the apparatus as shown in the figure. The pressure difference $\delta p = 17^{\text{cm}}$ was used throughout, as this is well within the lower limit of spontaneous condensation for the given receiver, while coronas may be obtained with X-ray nuclei for pressure differences even lower than $\delta p = 10^{\text{cm}}$. Such coronas are vague, however, until the rain nuclei are thrown out, and on second exhaustion ($n=39000$, $s=4.8$ were usual values after 4 minutes ionization) they are naturally faint.

The immediate incentive to the work of the present section was given by the occurrence of elliptic distortions of coronas as shown in the following tables.

TABLE 6.—Distorted coronas. Increasing times of exposure to X-rays. $\delta p = 17^{\text{cm}}$. Coronal center 19^{cm} (A-side) and 46^{cm} (B-side) from bulb. Angular aperture $\phi = s/30$.

Time	2 min.	
Side	A	B
First exhaustion,	$s = 4.5$, elliptic, strong	$1.0?$ faint, circular
Second “	$s = 2.7$, circular	2.4 circular
First “	$s = 4.6$, elliptic, strong	0.0
“ “	$s = 4.6$, “ “	0.0

TABLE 7.—Preceding table continued.

Time	1 min.		2 min.		3 min.	
Side	A	B	A	B	A	B
$s =$	3.1 , round, 0		4.1 , elliptic, 0		5.8 , ellipse, larger 0	
	strong		strong		and distorted	

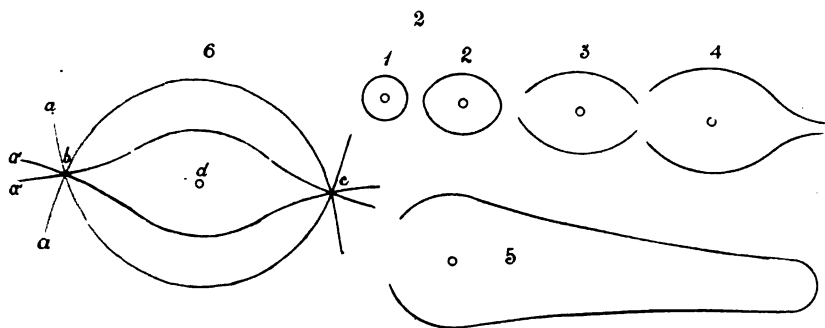
On second exhaustion, after refilling with filtered air, the coronas were nearly identical on both sides.

A series of observations was now systematically carried out, unfortunately with somewhat weaker radiation. After 1, 2, and 3 minutes of exposure, respectively, the coronas on the A-side were round to roundish (cf. figs. 1 and 2), of gradually increasing strength and density, and with rainy precipitation and fog usually marked. There was nothing on the B-side even after 6 minutes of exposure.

After 4 minutes (cf. fig. 3), the corona became spindle-shaped, $s = 5.4^{\text{cm}}$ in major axis, accompanied by rain from horizontal layers of fog.

After 6 minutes of exposure to the X-rays, the coronas underwent remarkable distortion, becoming gourd-shaped (fig. 4), often with a long, serpentine neck, dipping into the B-side of the condensation chamber. The length of figure on the goniometer was about 6.8^{cm} , the outline being orange and the field within greenish. Rain and fog abounded. The coronas on second exhaustion (after adding filtered air) were g-b-p, $s = 4.9$, $n = 42000$ and w-r-g, $s = 4.5$, $n = 32000$, on the A and B sides respectively. The experiment was repeated with like results.

After 8 and 11 minutes of exposure, both the A- and B-side became the seat of the now wedge-shaped corona (cf. fig. 5),



greenish within and orange in outline. There was much rain and fog.

The figures, 1-5, are seen immediately after the exhaustion. A moment later there is a storm-like disturbance in the condensation chamber, accompanied by rain and fog. Hence the distribution of nuclei found on exhaustion is incompatible with a persistent distribution of fog particles. In fact the first coronas usually fall out rapidly, showing the occurrence chiefly of large fog particles in spite of the horizontal extent of the corona. The second coronas are circular and persistent, whence a nearly uniform distribution of nuclei may be inferred.

9. *Symmetrically graded sizes or numbers of fog particles.*— Since the coronas obtained all show an unmistakable tendency to horizontal symmetry with reference to the longitudinal axis of the condensation chamber, the nuclei to which the coronas are due must either originate in, or else be absorbed by, the top and bottom of the apparatus. Nuclei originating or lost at the front and rear faces are nearly uniformly distributed normal to the line of sight and produce circular coronas. Nuclei origi-

nating or lost at the left hand end of the chamber will additionally distort the corona, and such distortion is in evidence.

Mere inspection of the coronas, 1-5, shows that they are larger for fog particles near the axis, and smaller for particles near the top and bottom of the condensation chamber. Hence it is next necessary to explain that the details of the distorted coronas observed actually correspond with a gradation of the number of *effective* or available nuclei, from the axis outward on all sides. In the case of linearly graded fog particles increasing in diameter, δ , from bottom to top (h), it appears that the equation of the apertures, s , of the loci* of like color of the coronas is

$$s = -\frac{\delta_0}{a \sin \phi} \left(1 - \sqrt{1 + \frac{2 a s_0 \sin \phi}{\delta_0}} \right),$$

where s_0 is the aperture of the particles of diameter, δ_0 , in the horizon or plane of sight, and ϕ the angle in polar coordinates between the radius vector to the part of the corona in question and the horizontal, the origin being at the center of the corona. Finally $\delta = \delta_0 - ah$, where $2h = s \sin \phi$. Such coronas when the gradation becomes marked are *campanulate* in outline, finally becoming basin-shaped.

In the present case, however, there are two symmetrical distributions of this kind, i. e., increasing diameters of fog particles from the axis of the chamber towards the top and the bottom. Hence pairs of intersecting curves, two examples of which are given in figure 6 ($a' > a$), show the coronas to be anticipated, if the remote parts beyond b and c of the corona are ignored, as they have no bearing on the symmetrical case, and only the curves surrounding the spot of light, d , admitted. In other words, as the distance bc , varying with the number of axial nuclei and the distribution constant a , increase, all the figures 1, 2, 3, 4, 5, may be logically evolved.

On the left end face, moreover, there would be special interference with the distribution of nuclei giving rise to the corresponding distortion seen in the coronas. Further distortion due to the decrease from left to right of the intensity of the radiation must also be apparent, and the gradient of distribution will be slightly altered by diffusion. One may note that if anything issues from the walls of the vessel, it comes as abundantly out of the water below as out of the wet cloth above.

10. *Origin of nuclei at the walls of the receiver.*—As has already been suggested, the observed gradation of fog particles may result from the (real or virtual) evolution of effective nuclei at the top and the bottom of the apparatus, in conse-

* Barus : this Journal (4), xiii, p. 309, 1902.

quence of the impact of X-rays on those parts, associated with secondary radiation. There is much electric evidence against such an explanation; nevertheless it is worth a brief examination.

The enormous coronas which have been obtained with the above (shallow) apparatus as compared with the small coronas seen in the cases of more bulky apparatus is in keeping with this view. Again, the rapid decrease of the nucleating power of the X-rays is to some extent referable to the increasing obliquity of the rays.

The observed distortion of coronas is clearly due to a gradation of nuclei, *either as to size, or number, or both*. If efficient nuclei issue from the top and bottom they must be present in greatest number near those parts of the apparatus, and consequently the largest diameter of coronas should apparently be found there. But if the largest number of effective nuclei is present near the top and bottom, the tendency to growth by cohesion will also be most marked in those regions. Hence the largest nuclei must be looked for nearest the top and bottom, while the gradation in size decreases regularly towards the axis. The large nuclei, therefore, may be sufficiently numerous near the walls to capture all the available moisture on condensation, leaving the small nuclei without a load of water and unable to descend. Hence the marked rain effect, the rapidity with which the first coronas usually drop out, the turbulent motion which succeeds condensation, the occurrence of large persistent coronas on second exhaustion even after the first coronas have quite dropped out, etc.

Finally one may note that secondary radiation issuing from the top and the bottom of the condensation chamber would accentuate the present effect.

Thus it seems not unreasonable to infer that nuclei are produced by the impinging X-rays in much the same way in which they are produced by high temperature (ignition), or by high potential; and the question arises whether the nuclei thus easily set free may not be associated with the electrons to which the cohesions between the molecules may be ascribed.

11. *Absorption of the ions at the walls of the receiver.*—If the nuclei due to the ionization of air by the X-rays are absorbed at the walls of the receiver* a diffusion gradient will be established, resulting in a decreasing number of nuclei from the axle outward, a distribution the reverse of the preceding. The observed distortion will, therefore, here be due to a gradation in the number of nuclei.

* A number of similar cases have been worked out in Smithsonian Contributions, No. 1809, 1901, "Experiments with ionized air;" and *ibid.*, No. 1873, chapter v, 1903.

The difficulty in the present instance, however, seems to be fatal; for no reason is suggested why the coronas on second or third exhaustion do not eventually show flowerlike distortion, which they never do. In other words, it is here tacitly assumed that only the ions in the "nascent" state, as it were, are appreciably diffusible, while the nucleus is relatively a fixture. Again, the effect of secondary radiation is ignored.

12. *Conclusion.*—To decide between these hypotheses it is necessary to guide the X-rays by screens, suitably placed both on the inside and the outside of the apparatus; but these experiments are still in progress.

Here there is room only for a final remark. Whenever nucleation and ionization are associated as the outcome of any process (physical or chemical), the former is generated proportionally to the latter, in such a way that each is produced at its own rate depending on incidental conditions. This is best worked out with water nuclei. The subsequent life-history of the nucleation and the ionization is distinct, nuclei being surprisingly persistent, ions by contrast characteristically fleeting. Hence it seems to me to be best in keeping with all the data in hand, to regard the nucleation as the product which owes its growth or origin to the expulsion of the corpuscles representing the concomitant ionization. Ignition and high potential nuclei, X-ray and radiation nuclei in general, phosphorus and water nuclei, produced throughout in strictly dust-free air, all admit of this account of their occurrence and properties. There is no observable case of a process producing ionization without nucleation, although there are many cases of nucleation free from ionization.

It should be noticed that to produce the condensation on the X-ray air nuclei here in question, less than a twofold supersaturation is needed; whereas in case of condensation on ions the supersaturation prescribed is three to fourfold. The two views are not, therefore, mutually exclusive. Moreover, if initially, i. e., for short exposures and nuclei in the extreme state of fineness antedating growth, the nucleus is supposed to have ejected but one electron per nucleus (an assumption which in one form or another must be made in any explanation), the present view is in no way incompatible with J. J. Thomson's method of measuring the charge of one electron. Finally if a nucleus like that of phosphorus shows a tendency to grow continuously until it finally appears as part of a visible smoke, there may be continuous ejection of electrons within certain limits, as the growth matures. Electric conduction through a gas freighted with these nuclei would obey Ohm's law, as is actually the case for phosphorus.

Brown University, Providence, R. I.

ART. XII.—*Radio-active Measurements by a Constant Deflection Method*; by HOWARD L. BRONSON.

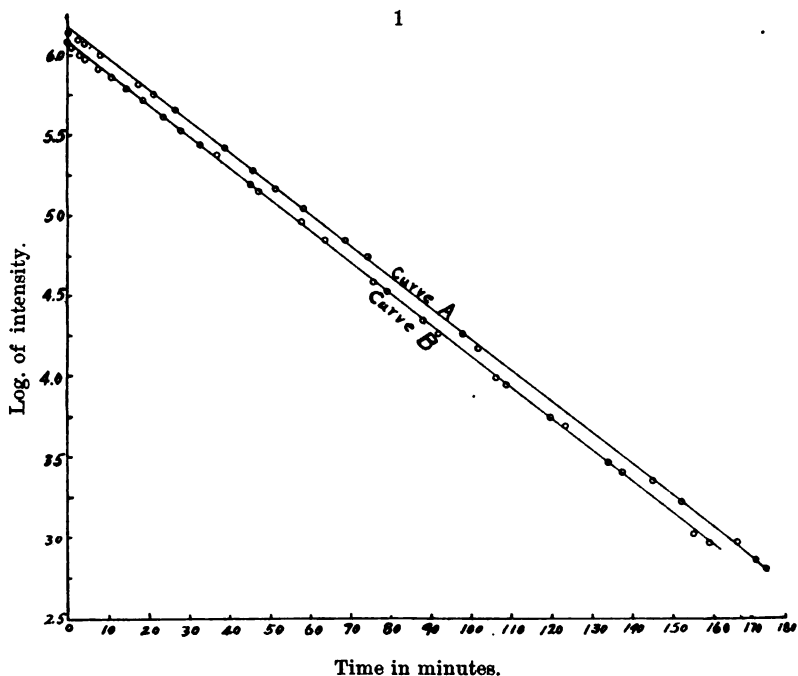
THE ordinary method of using an electrometer for comparing ionization currents through gases has been to measure the rates of movement of the needle. The ionization currents are then proportional to these rates, if the following conditions are fulfilled: (1) that the capacity of the system remains constant, (2) that the deflection is proportional to the potential of the quadrants, (3) that the lag of the needle behind the potential is the same for different rates. In some cases these conditions are closely fulfilled, but in others, especially where the needle is moving rapidly, the last condition and probably the first are not. The introduction of additional capacity into the system, while it reduces the rate of motion of the needle, creates the added difficulty of comparing capacities, which not only takes considerable time but is never entirely satisfactory. Another difficulty with this method is that it is practically useless in the case of rapidly changing ionization currents. The desirability, therefore, of a more direct and rapid method of measurement is evident.

If, as usual, one pair of quadrants of the electrometer is connected to earth, and the other pair is not only connected to the testing vessel but also to earth through a very high resistance, it is easily seen that an ionization current in the testing vessel will charge the quadrants until the discharge current through the high resistance is equal to the ionization current. In this case the current will be proportional to the potential of the quadrants, that is, to the deflection of the needle.

Resistances of the order 10^{11} ohms made of pure amyl alcohol and of carbon on glass were tried, and gave results which compared favorably with those obtained by the "rate" method. The results, however, were not satisfactory, because in the case of the liquid resistance there seemed to be a variable polarization, whereas the resistance of the carbon was not perfectly steady. Professor Rutherford then suggested the possibility of using an ionization current in place of the conduction current through a high resistance. For this purpose he furnished a very radio-active bismuth plate from Dr. Sthamer of Hamburg. The activity of this plate was due to a deposit of the so-called radio-tellurium of Marckwald, which has such a long period of decay that it remains practically constant during any short experiment.

The bismuth plate was earthed and covered with a very thin sheet of aluminium to avoid contact potential difference. Another aluminium plate was placed parallel to this and connected to the same quadrants as the testing vessel, and the

whole was protected from air currents. The electrometer had a sensitiveness of about 150 scale divisions per volt, and with the plates 2^{cms} apart, the ionization currents were practically proportional to the deflections throughout the entire length of the scale (500 divisions). When the distance between the plates was increased to 2.7^{cms} the same deflection was produced by an ionization current only one third as large, that is, the sensitiveness of the apparatus was tripled; on the other hand, the current was proportional to the deflection for only about 150

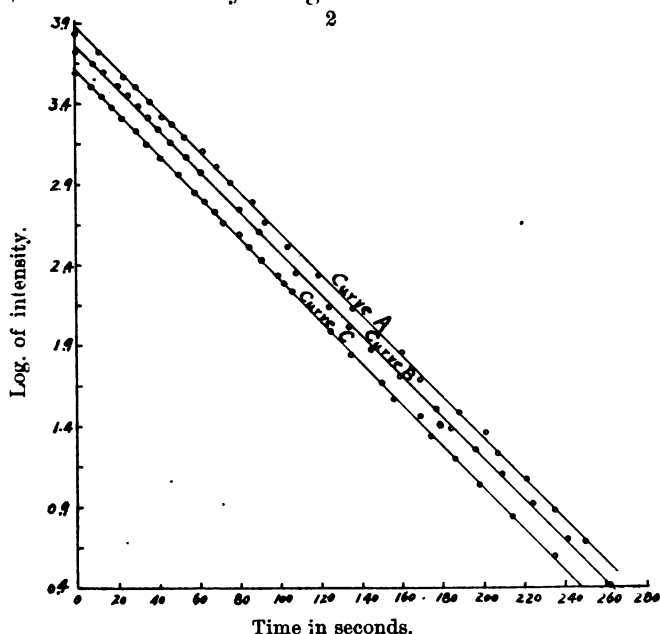


divisions. The currents measured varied from about 10^{-12} to 10^{-10} amperes.

The advantages of this method are obvious; deflections are independent of the capacity, measurements can be made over a large range without readjustment, and observations can be taken in as rapid succession as desired. In some cases observations were taken as often as once in five seconds. Figs. 1 and 2 show the accuracy which can be obtained by single sets of observations.

A and B, fig. 1, are two similar logarithmic decay curves of the excited activity of actinium, and should therefore be parallel. The time 0 was at least 20 minutes after the emanation was removed, so that the initial rise of the excited activity is not shown. The equation of the decay of any radio-active sub-

stance is given by Rutherford (Radio-activity, p. 258) as $I = I_0 e^{-\lambda t}$. From curve A, λ is found to be 0.0193, and from curve B, 0.0195, where the time is measured in minutes. The mean of these two values gives 35.7 minutes as the time required for the excited activity of actinium to decay to half value. This is a rather shorter time than was found by Debierne (Comptes Rendus, No. 138, p. 491), and verified by Miss Brooks (Phil. Mag., Sept., 1904). This smaller value, however, was confirmed by a large number of observations taken



by the "rate" method. The values thus obtained varied considerably, but their mean was about 36 minutes.

Fig. 2 shows three logarithmic decay curves for thorium emanation, which on account of its rapid rate of decay has been found so difficult to measure. By this method the observations for the three curves were taken in about thirty minutes. The value of λ obtained from curve A is 0.0129, from curve B is 0.0127, and from curve C is 0.0128,—a very satisfactory agreement for single sets of observations. A mean value of these λ 's gives about 54 seconds as the time taken for the emanation to decay to half value, which agrees fairly well with the value 51.2 seconds recently obtained by C. Le Rossignol and C. T. Gillingham (Phil. Mag., July, 1904).

Macdonald Physics Building,
McGill University, Dec. 20, 1904.

ART. XIII.—*A Convenient Apparatus for Determining Volatile Substances by Loss of Weight*; by J. LEHN KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxiii.]

OF THE various forms of apparatus designed for the determination of volatile products of reactions, some are cumbersome and many require for their construction skill in glass-blowing. The apparatus here described is light and easily made from three test-tubes, modified and fitted as shown



in the figure. The test-tube, A, is changed in no way from its original form; B is perforated, in the bottom, with a hole about 1^{cm} in diameter and fits tightly within A; and C, so selected that it fits loosely within B, is drawn out to a small capillary tube.

When the apparatus is to be used, the capillary of C is pushed through the hole of B, packed loosely with cotton; B is filled to the depth of from 6^{cm} to 8^{cm} (about two-thirds of its contents), with granular calcium chloride; and B and C are adjusted as shown.

To the test-tube, C, is fitted a one-holed stopper, through which passes a short glass tube which is to be closed by a rubber cap and plug. Upon removing the plug, and applying suction to the short tube, the reagent employed to liberate the volatile product to be determined is drawn up through this capillary until C is sufficiently filled.

Upon replacing the plug the reagent remains within C, held by atmospheric pressure.

The tubes A and B may be so selected that very little of the product evolved can escape between them, but in case they fit very loosely, a ring of paraffine melted into the mouth of A, about B, by means of a hot iron or wire, seals the joint securely. A very convenient way to attach the paraffine is to melt it between A and another tube, which fits A, as does B, and may be removed by a turning motion, leaving the ring into which B will fit, and which then requires very little heating to make a tight joint. If care be used in taking apart A and B, at the close of an experiment, such a ring of paraffine remains in place and may be used many times without replacement, being remelted by a touch of the hot wire before every new experiment.

In making a determination, the substance under examination is weighed and placed in the bottom of A. The reagent to be employed, 10^{cm}³ to 15^{cm}³, is drawn into C, and held there in the manner described. The test-tube A is slipped over B, and

this joint is sealed with paraffine, as has been shown. The apparatus is wiped, placed on the balance, and weighed.

Upon removing the cap from the small tube in C, the reagent runs from C into A. The volatile product is formed, is forced upward through the drying column of calcium chloride, and escapes through the annular space between B and C. When the action ceases, a current of dry air is forced through C, to drive all the volatile product from the apparatus, the cap is then replaced, and the whole placed on the balance to be weighed. The loss of weight represents the volatile product.

The following results show the accuracy which may be expected when carbonates are treated in the apparatus with dilute hydrochloric acid :

TABLE I.

	Taken. grm.	Found. grm.	Error. grm.
Calcium Carbonate.	0.2000	0.0879	-0.0001
	0.2000	0.0878	-0.0002
	0.2000	0.0879	-0.0001
	0.2000	0.0879	-0.0001
	0.5000	0.2197	-0.0003
	0.5000	0.2196	-0.0004
	0.5000	0.2194	-0.0006
	0.5000	0.2198	-0.0002
	0.5000	0.2197	-0.0003
Barium Carbonate.	0.5000	0.2197	-0.0003
	0.5000	0.1134	-0.0011
	0.5000	0.1137	-0.0005
	0.5000	0.1137	-0.0005
Strontium Carbonate.	0.5000	0.1136	-0.0006
	0.5000	0.1485	-0.0004
	0.5000	0.1486	-0.0003
	0.5000	0.1485	-0.0004

In Table II are included the results of some experiments made to determine the weights of hydrogen liberated by the action of magnesium and zinc, upon dilute hydrochloric acid.

TABLE II.

	Taken. grm.	Found. grm.	Error. grm.
Magnesium Metal.	0.1000	0.0087	+0.0003
	0.1000	0.0085	+0.0001
	0.1000	0.0084	±0.0000
	0.1000	0.0084	±0.0000
	0.1000	0.0083	-0.0001
Zinc Metal.	0.2000	0.0061	±0.0000
	0.2000	0.0062	+0.0001
	0.2000	0.0062	+0.0001
	0.2000	0.0060	-0.0001
	0.2000	0.0061	±0.0000

Determinations of the nitrogen liberated from urea, ammonium oxalate, and ammonium chloride, by action of sodium hypobromite, are given in the following table:

TABLE III.

	Taken. gram.	Found. gram.	Error. gram.
Urea.	{ 0.1000	0.0469	+ 0.0003
	{ 0.1000	0.0467	+ 0.0001
	{ 0.1000	0.0467	+ 0.0001
	{ 0.1000	0.0468	+ 0.0002
	{ 0.1000	0.0467	+ 0.0001
Ammonium Oxalate.	{ 0.1000	0.0204	+ 0.0007
	{ 0.1000	0.0197	± 0.0000
	{ 0.1000	0.0198	+ 0.0001
	{ 0.1000	0.0198	+ 0.0001
	{ 0.1000	0.0196	— 0.0001
Ammonium Chloride.	{ 0.1000	0.0264	+ 0.0002
	{ 0.1000	0.0265	+ 0.0003
	{ 0.1000	0.0261	— 0.0000
	{ 0.1000	0.0263	+ 0.0001
	{ 0.1000	0.0261	— 0.0001

I wish to thank Prof. F. A. Gooch for his advice and kind assistance.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Canyon Diablo Meteorite*. — MOISSAN has made a new examination of a portion of this celebrated meteorite. When the mass was cut with a saw several very hard nodules were encountered which interfered greatly with the cutting operation. Upon dissolving a large mass of the meteorite, 53 kg., in hydrochloric acid, it was evident that the iron was not homogeneous, for it was attacked very irregularly. The hydrogen set free by this dissolving contained hydrocarbons, hydrogen sulphide, and hydrogen phosphide.

Certain samples taken from the exterior gave the following percentages: Iron, 95.64; nickel, 1.66. Iron, 95.26; nickel, 2.56. Iron 94.03; nickel, 3.61. Iron 96.31; nickel, 1.83. A sample of specific gravity 7.703, taken from the interior, gave: Iron, 95.370; nickel, 3.945; phosphorus, 0.144; insoluble in HCl, 0.260; silicon, traces; sulphur, traces; carbon, not determined.

A nodule, cut out with a chisel, gave the following analysis: Iron, 66.95; nickel, 1.93; cobalt, traces; sulphur, 22.15; phosphorus, 2.37; silicon, small quantity; magnesium, traces; carbon, 1.96.

The residue from dissolving 53 kg. in hydrochloric acid weighed 800 g. It consisted of a coarse powder, containing brilliant needles and cubes, both of which gave analyses corresponding closely to the formula P_2Fe_3 , and contained only traces of nickel and carbon. In the residue which remained after treatment with concentrated hydrofluoric acid and boiling sulphuric acid, characteristic green hexagonal crystals of carbon silicide (carborundum) were found. This is the first time that this compound has been found in nature.

A part of the carbon in the meteorite escaped in the form of hydrocarbons upon dissolving it in hydrochloric acid, but the 800 g. of residue previously referred to contained 5.04 per cent of carbon. Five forms of carbon were noticed in this residue: A light, impalpable powder; jagged, slender fragments of a light color, which seemed to have been agglomerated by pressure; graphite, very rarely crystallized; smooth, black diamonds, abundant, but very small; transparent diamonds in the form of octahedrons with rounded edges. — *Comptes Rendus*, cxxxix, 773. H. L. W.

2. *Metallic Calcium*. — An examination of some of the chemical and physical properties of this metal has been undertaken by K. ARNDT. The metal is now produced on the large scale by the electrolysis of fused calcium chloride, so that it is easily procured. Metallic calcium is ductile, and can be hammered and chiselled like brass, and it clogs a saw or a file. The fresh surface of the metal is brilliant, but it becomes yellowish rapidly, particularly in moist air. (The metal was formerly supposed to possess a

yellow color.) A piece of calcium reacts slowly with water on account of the difficult solubility of the hydroxide, but if a little hydrochloric acid is added, the evolution of hydrogen is violent. A sample of the commercial metal was found to contain 0.2 per cent of silicon and 0.3 per cent of aluminium with traces of iron. The hydrogen produced from it was very pure, and contained no appreciable amount of acetylene or other hydrocarbons. The specific gravity of the metal was found to vary considerably in different samples; a very pure specimen gave 1.52 as the result. In this investigation the melting-point was not very exactly determined, but it was near 800° . The metal begins to vaporize in a vacuum below its melting-point, and forms beautiful crystals which are free from silicon and aluminium. The vapor of calcium reacts very energetically—much more so than magnesium—with any residue of air that may be in the tube in which it is heated. In this way a very complete vacuum may be obtained from an imperfect one.—*Berichte*, xxxvii. H. L. W.

3. *The Use of Dried Air in Blast-furnaces.*—The employment of air dried by refrigeration, a process due to Mr. Gailey and applied at the Isabella Furnaces near Pittsburgh, has received considerable attention of late in the technical journals. The advantage attributed to the removal of the moisture from the air used for blast depends upon the fact that water is decomposed by incandescent carbon with the absorption of heat, and with the direct loss of carbon, by the reaction

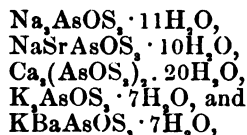


and it is claimed that a gain of 20 per cent is made in the efficiency of the fuel.

The process has been recently discussed by LE CHATELIER, in France, from a scientific point of view, and he maintains that the gain in efficiency attributed to the process is about four times greater than the theoretical maximum obtained by calculation. He puts forward the view that the advantage is partly due to a possible effect of the dryness of the air upon the removal of the sulphur from the pig-iron, and supports this opinion by the results of experiments in which it was found that dry carbon monoxide free from hydrogen does not remove sulphur from heated calcium sulphide, while the gas when mixed with hydrogen removes it with considerable rapidity.—*Comptes Rendus*, cxxxix, 925.

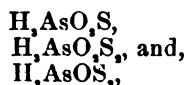
H. L. W.

4. *Trisulphoxyarsenic Acid.*—McCAY and FOSTER have prepared the salts



which represent a heretofore missing member, H_3AsOS_3 , of a series of acids intermediate between H_3AsO_4 and H_3AsS_3 , concerning

which most of our knowledge is due to McCay and his pupils at Princeton University, viz.,



These sulphy acids have not been isolated, and only the first two appear to exist in dilute solutions.

The trisulphoxyarsenates are usually colorless, crystalline, rather unstable compounds. The sodium salt is prepared by acting in the first place upon arsenic pentasulphide with a large excess of magnesium oxide in the presence of water, whereby the sulphide dissolves; then precipitating magnesium hydroxide by means of sodium hydroxide and removing it by filtration, adding alcohol to the liquid until a turbidity begins to form, and finally cooling to crystallization.—*Zeitschr. anorgan. Chem.* xli, 452. H. L. W.

5. *The Electrolysis of Solid Electrolytes.*—It has been found possible by HABER and TOLLOCHKO to electrolyze solid barium chloride at a temperature about 400° below its melting-point. When barium carbonate had been mixed and fused with the barium chloride, carbon was produced at the cathode in quantities corresponding to the electric current employed, but when the barium chloride was free from carbonate, barous chloride formed quantitatively. In both cases the result may be assumed to be due to the reaction of metallic barium with the substances present. The experiments were conducted in nickel crucibles with careful regulation and measurement of the temperatures. Attempts to electrolyze sodium hydroxide were not successful when the substance was perfectly solid.—*Zeitschr. anorg. Chem.*, xli, 405.

H. L. W.

6. *The Determination of Fluorine in Wine and Beer.*—On account of the frequent use of sodium fluoride as a preservative, particularly for French, Spanish, and Greek sweet wines, and because of the poisonous effect of this preservative, which appears to have been established by the results of several investigators, TREADWELL and KOCH have undertaken the examination of various methods which appeared applicable to the determination under consideration.

No easy method for performing this difficult determination was found, but interesting results in regard to the accuracy of the standard methods, and the limits within which fluorine can be detected qualitatively, were obtained. A slightly modified apparatus for the determination according to Penfield's method is described and figured.—*Zeitschr. analyt. Chem.*, xliii, 469.

H. L. W.

7. *Direction and Velocity of Electric Discharges in Vacuum Tubes.*—Wheatstone in 1835, by means of a rotating mirror, arrived at the conclusion that this velocity was not less than 8×10^7 cm. per second; Plücker from observations in a magnetic field, concluded that the discharge emanated from the positive elec-

trode. Spottiswoode and Moulton found that the time which the positive electricity needed to traverse the tube was shorter than that which the negative electricity required to leave the cathode. They believed that the time occupied by a discharge to traverse a metallic conductor was much shorter than the time required through a discharge tube. J. J. Thomson took a discharge tube 15^m long, blackened it except at two points; threw an image of these two points on a cylinder. When the cylinder was at rest, the points or slits were directly over each other; when the cylinder was set in rapid revolution the images of the points separated. When the current was reversed, the images exchanged position. He concluded that the discharge was independent of the nature of the electrodes and always proceeded from the anode to the cathode, and that for a pressure of 0.8^{mm} the velocity of the discharge was approximately half that of light. E. Wiedemann and G. C. Schmidt have shown that under certain conditions an apparent velocity of 200^m per second can be observed. Wüllner, Rhigi and others have noticed an extraordinarily slow velocity. On account of the divergence of results J. JAMES has studied the question of the velocity in discharge tubes by means of the Abraham-Lemoine method of measuring small intervals of time. This method consists in employing changes in polarization of light in the magnetic field, or by electric stress. By these means a time interval of one hundred millionth of a second can be detected. James gives an analytical discussion of his employment of the method which he used to study the discharge of the electric spark in air, and also in a discharge tube. He found results which did not agree with those obtained by J. J. Thomson. They did agree, however, with those of Spottiswoode and Moulton. Further investigations are needed to determine whether from a study of the kind of illumination one can draw conclusions in regard to velocity.—*Ann. der Phys.*, No. 15, 1904, pp. 954-987.

J. T.

8. *Extinction of the Electric Spark*.—Wireless telegraphy and the study of N-rays give a great interest to the study of the electric spark. JOHN KOCH discusses conditions of residual charges of condensers and the fall of potential and other conditions which accompany or cause extinction. He concludes that the causes which lead to this extinction are purely electrodynamic and are identical with those connected with the dying out of the voltaic arc. The author concludes that Heydweiller's contention, that the development of energy is proportional to the time of discharge and independent of the current strength, is true only to a first approximation, when very great resistances are in the circuit.—*Ann. der Phys.*, No. 15, 1904, pp. 866-905.

J. T.

9. *Exhaustion of Geissler Tubes by the Electric Current*.—It has often been noticed that the degree of exhaustion in Geissler tubes, and notably in X-ray tubes, is changed by long continuance of electrical discharges. At first the heat of the discharge increases the pressure and then there comes a lowering of the pressure

which indicates occlusion or absorption of the rarified gas in the glass walls of the tubes. EDUARD RIECKE has studied this soaking in effect in the case of nitrogen. He compares the effect of mere gas absorption with the absorption induced by the electrical discharges and estimates the connection between the strength of current and the resulting diminution of pressure.—*Ann. der Phys.*, No. 15, pp. 1003-1009. J. T.

10. *The N-rays*.—Authorities are still divided in regard to the existence of these rays. A. BROCA (Archives d'El Medicales, pp. 723-740, Oct. 10, 1904) points out that the observation of these rays is an extremely delicate one; in his own case it was six weeks before he could see the rays. He submitted himself to an elaborate course of training and he gives an account of the best way of studying the rays. He dwells upon the necessity of observing physiological conditions. Thus the eye must be adapted to almost completed darkness or at least to very feeble lights. The observer must be left with his mind free, all instrumental changes being intrusted to another. The effects due to heat must be borne in mind; for the physiological radiations can be entirely swamped by the heat effects. The two effects can be distinguished by the slight lagging (up to a few seconds) behind of the effect due to the N-rays, such lag being much greater in the case of the heat effect; and on the cessation of the action the difference of lag is even greater. The N-ray effect may also be distinguished by the different behavior when viewed normally, at 45° , and at grazing incidence.—*Science Abstracts*, Dec. 27, 1904.

It is stated in the *Revue Scientifique* of Nov. 26 that M. d'Arsonval has been able to reproduce the N-rays and to show that they are not due to heat. Mascart is stated to have observed the phenomena with D'Arsonval.—*Nature*, Dec. 15, 1904.

J. T.

11. *The Recent Development of Physical Science*; by WILLIAM CECIL DAMPIER WHETHAM, M.A., F.R.S., Fellow of Trinity College, Cambridge. pp. 445, 8vo. Philadelphia, 1904 (P. Blakiston's Son & Co.).—At a time like the present, when the public in general is more than ever before keenly alive to the progress made in science, it is most useful to have the topics of immediate interest presented in a form so simple and clear that anyone who is well grounded in the fundamental principles can gain a good understanding of what is being done. This is eminently true of the book in hand, which, in a series of eight chapters, gives an admirable presentation of some of the subjects in physics, which are just now of greatest interest and in which progress has been and is being made. The author has a thorough command of his subject, and has also had the advantage of assistance from various specialists in the different lines. Some of the subjects dealt with in the eight chapters are: the liquefaction of gases, fusion and solidification, solution, electric conduction through gases, radio-activity, atoms and ether. The frontispiece is a representation of the well-known statue of Newton, and portraits of Lord

Kelvin, J. J. Thomson, van't Hoff, with other illustrations, are scattered through the volume.

12. *Outlines of Physiological Chemistry*; by S. P. BEEBE and B. H. BUXTON. 195 pp. New York, 1904 (The Macmillan Co.).—The title of this little book is perhaps somewhat misleading if it gives the impression of any systematic review of the subject. The aim of the authors is rather to deal with the theoretical side of the various chemical questions arising in physiology, and to explain the nature of the more important reactions with which the student has to deal. The book includes chapters on the theory of solutions, and on the chemistry of the carbon compounds; the more distinctly physiological part is almost entirely devoted to the proteids and to enzyme action. The current theory of immunity is also outlined.

L. B. M.

I. GEOLOGY AND MINERALOGY.

1. *Geological Survey of Canada*, ROBERT BELL, Acting Director. Annual Report, vol. xiii, 1900, 747 pp., 8 maps, 15 pls.—The Canadian survey reports are always of interest because of new territory explored and the geological reconnaissance which is being carried on. The present report shows that a great amount of work in several lines is being accomplished at small expense. The principal papers bound in the volume are: Exploration of East Coast of Hudson Bay and Geology of Nastapoka Islands, by A. P. LOW; Parts of Saskatchewan, Athabaska, and Keewatin, by J. B. TYRRELL, and also by D. B. DOWLING; Basin of Nottaway River, by ROBERT BELL; Geology and Petrography of Shefford Mountain, Quebec, by J. A. DRESSER. These papers have been previously issued separately.

Dr. Low's investigations show that the land about Hudson Bay is now 700 ft. above the level during the ice age. He finds no evidence of present elevation. (For the contrary view see article by Dr. Bell in *Geol. Soc. Am.*, 1895.) The key to the stratigraphic problems in the Cambrian, which shows buckling and nearly horizontal movement, is found in the contraction of intruded granite masses. "The contacts of the bedded rocks and granites are usually unconformable and appear to be due to a nearly horizontal movement of the bedded series subsequent to the intrusions of the granite, due to pressure acting from outside the great areas of granite. This series of sedimentary rocks being close to the surface broke as does ice upon the shore when pressed from seaward and piled cake on cake not only upon unyielding granite but upon themselves."

2. *The Iowa Geological Survey*, SAMUEL CALVIN, State Geologist: Vol. xiv, Annual Report of 1903, 655 pp., 38 pls., 132 fig.—The last annual report of the Iowa Geological Survey is chiefly economic in character, and in addition to the annual statistics contains an extensive treatment of clays and clay products in general with special reference to the Iowa deposits. At the present time

the clay products of Iowa stand second in value only to the output of coal. The survey is also collecting data relative to the artesian waters in Iowa, and plans to publish a report on the same. The U. S. Survey has completed the topographical work in northeastern Iowa, so that the state survey will now work out the details of geology in that section. An investigation is in progress regarding the coals of Iowa, their occurrence, physical and chemical characteristics, geological and geographical relations.

3. *Glaciation in South Africa*.—At the October meeting of the Geological Society of South Africa, Mr. M. E. FRAMES describes the geology of the Amsterdam Valley. Part of the village of Amsterdam is built on a glacial moraine of undoubted Dwyka structure and age. As had been shown before, a direction of glaciation which resulted in the deposition of the Dwyka is proved to have been from the north. This view has recently received support from the fact that a characteristic porphyritic rock which is found in the conglomerate at Amsterdam has been discovered *in situ* forty miles to the north. A large outcrop of this rock has been discovered on Bonnie Braes farm near Oshoek.

4. *Ueber Untersilur in Venezuela*; von Dr. FR. DREVERMANN. Neues Jahrb. f. Min., Geol. u. Pal., 1904, pp. 91-93, pl. x.—This little paper is of great interest in that it proves the occurrence of lower Paleozoic deposits on the north side of the Venezuelan-North-Brazilian shield. Engineer Klein, in traveling from Caracas over Valencia to Puerto Cabello, collected a few fossils which Dr. Drevermann thinks are indicative of Lower Silurian age. These specimens are *Calymmene senaria* like those from Cincinnati, Ohio, and *Orthoceras cf. olorus* Hall. As no Ordovician formations are known in northern South America the reviewer raised the question—Are these fossils probably of Silurian age? With this in view he addressed the author of the present paper, under date of August 3, 1904, as follows: "The *Calymmene* is nearer to *C. niagarensis* than to *C. senaria* (= *C. callicephala*). . . . As for *Orthoceras cf. Volorus* it may be one of several of our Niagaran annulated forms. Its size is so large that I think it rather a Niagaran species.

"On the other hand, in Brazil on the south side of the old land mass there is good Upper Silurian, which as you know was described by Clarke. All in all I feel that the Venezuela fossils are of Upper Silurian age." On October 25 last, Drevermann replied as follows: "I have had another opportunity to compare the *Calymmene* of Venezuela with the North American material kindly sent me by you. An identity with *C. niagarensis* I cannot agree to in spite of the extraordinary similarity heightened by the fact that both examples are preserved in dolomite. The lower lobe of the glabella of the Venezuelan specimen is much larger than in *C. niagarensis* and the latter in this respect reminds one of *C. callicephala* (respectively *C. senaria*). The head of *C. niagarensis* is also considerably more arched. On the other hand, the South American example agrees with *C.*

niagarensis in regard to the distance of the facial suture from the posterior margin.

"The certainty that the specimen is of Lower Silurian age is therefore shattered; it may be that it is Upper Silurian and in this case it would be according to your view about Niagara. The *Orthoceras* is unfortunately not diagnostic." C. S.

5. *Devonian Fauna of Kewataboahagan River*; by WILLIAM ARTHUR PARKS. Rept. Bureau of Mines, 1904, Pt. I, pp. 180-191, pls. 1-8.—This paper is of much importance because it gives one a clear understanding of the facies of the Devonian fauna found on the west side of James Bay, heretofore a rarely visited region. The reviewer has elsewhere discussed this fauna, and before Professor Parks's much larger list was made known (*Amer. Geol.*, Sept., 1903, pp. 153, 154). He then stated that the "fauna as listed by Whiteaves shows unmistakably that their age is about that of the Corniferous (Onondaga)."

The reviewer has enjoyed the privilege of studying the collection belonging to Professor Parks; hence some of the species here cited appear under other names than in the work reviewed. The following list is not complete, only the more significant species being mentioned: *Syringopora nobilis*, *S. perelegans*, *S. hisingeri*, *Diphyphyllum simcoense*, *Phillipsastræa* (?) *gigas*, *P.* (?) *verneuili*, *Crepidophyllum archiaci*, *Favosites basaltica*, *F. hemisphaericus turbinatus*, *Romingeria umbellifera*, *Heliohyllum exiguum*, *Stropheodonta demissa*, *S. crebriatriata*, *Strophonella ampla*, *Chonetes lineata*, *Spirifer grieri*, *S. unicus* (the Onondaga form of the Oriskany *S. arenosus*), *Meristella nasuta*, *Atrypa reticularis*, *Amphigenia elongata undulata*, *Conocardium cuneus trigonale*, *Callonema bellatulum*, *Platystoma lineatum*, *Pleurotomaria lucina*, *Bellerophon pelops*, *Orthoceras tantulus*, *O. thoas*, *Calymmene platys*, *Dalmanites archiops*, *D. (Synphoria) stemmatus* (an Oriskany species), and *Phacops cristata*.

The author states: "It would also appear that the organisms denote an age comparable with the bottom of the Upper Helderberg. In some cases the assemblage would denote the Oriskany." These conclusions are undoubtedly correct, for the Onondaga as seen about Decewville, Ontario, has a large percentage of Oriskany species, but has not *Spirifer unicus*. The latter, however, occurs in the Onondaga not far to the southeast, in Erie county, New York. In general the James Bay Devonian holds the horizon of the Onondaga and has many of the diagnostic species of the Schoharie grit and Onondaga, and at least one of the very characteristic Oriskany brachiopods.

The former conclusion of the reviewer "that the faunal facies is more that of the Mississippian type than any other known" is, through this collection of Professor Parks, brought into closer and more decided harmony with the typical Onondaga of New York. It is clearly established that this fauna did not continue westward into the Manitoba-Athabasca region, as here are known

formations somewhat younger, with the *Stringocephalus* fauna of the Euro-Asiatic type. C. S.

6. *Ueber den Bau und die Organisation der Lyttoniidæ Waagen*; by Dr. F. NOETLING. Verh. Deutsch. Zool. Gesellsch., 1904, pp. 103-122.—On the basis of excellent etched material, this author here revises the remarkable brachiopod family Lyttoniidæ, the genera *Oldhamina* and *Lyttonia*, and the species *O. decipiens* and *L. nobilis*. In 1901 Noetling (Neues Jahrb., Beil.-Band xiv, p. 452, foot-note) thought that *Oldhamina* was a "remarkable type of Bryozoa," and because of the similarity of the name to *Oldhamia* he proposed to change it to *Waagenopora*. Under the rules of nomenclature, this change of name can not be made. In the present paper, Noetling says nothing of this proposed name or of his former view as to the nature of these peculiar brachiopods. Other authors have regarded *Oldhamina* as a gastropod and *Lyttonia* as fish teeth, but Noetling's work makes it very clear that we are here dealing with degenerate brachiopods related to *Strophalosia* by the concavo-convex form of the valves and especially by the cardinal process of the dorsal valve, the dental plates, and the fixed or cemented nature of the ventral valve.

The author correctly states that these forms can not be brought into relation with terebratuloid types like *Megathyris*, but does not seem to have noticed the conclusion of Beecher and Schuchert that the affinities of these brachiopods are near the Thecidiidæ as defined by the latter authors—forms closely related to the strophomenoids. Noetling's work makes it now necessary to remove the Lyttoniidæ from the family Thecidiidæ and to associate them as a family with the productoids. The family Lyttoniidæ had its origin probably in *Strophalosia* in Upper Carboniferous time, and is to be regarded as an aberrant and degenerate branch of that genus.

According to Noetling, the great number of so-called "lateral septa" of the ventral valve may be regarded "as supports for the lobes of the dorsal shell," or he thinks "that both median stems of the mantle sinus lay in the space on both sides of the median septum. From the latter came the side branches and continued in form as broad, flat, vascular strands between the lateral lamellæ." The reviewer does not regard these markings as due to the mantle sinus nor as supporting septa, but believes that they are caused by the lobations of the brachia. In the productoids the brachia are in the early ptycholophus or latest schizolophus stage, as may be seen by the reniform markings in many species, yet in the Lyttoniidæ, owing to the progressive elongation of the shell, the brachia are longer and much more numerously lobed, with the lobes directed laterally. Some of this evolution is shown in the oldest *Oldhamina* (?) of the Carnic Alps, described by Schellwien, having but six anteriorly directed lobes; and in the *Keyserlingina* with the same number of laterally directed lobes, recently described by Tschernyschew. In the

most recent *Oldhamina* and *Lyttonia*, however, there are from fourteen to forty lobes. The latter represent the highest expression of the ptycholophus stage of brachial development in brachiopods (see Beecher, Bull. U. S. Geol. Surv., No. 87, 1897, p. 108). In the dorsal valve the lobes of the brachia lie between the elevations, while the so-called lateral septa of the ventral valve lie between the recurved bands of each brachial lobe.

Noetling thinks that *Oldhamina* lived with the "dorsal valve directed downward and probably partially buried in the mud." This is an anomalous mode of life for any brachiopod other than *Lingula*. The early cemented condition of these shells indicates that *Oldhamina* lived like other related forms, i. e., with the ventral valve underneath.

The Lyttoniidae are known in India only in the Upper Permian, i. e., in the Middle or Upper Productus-limestone. They are also known in the Himalaya; at Loping, China; Rikuzen, Japan; near El Paso, Texas, and in Nevada. The occurrence of the older forms has been mentioned above.

Noetling concludes: "Against one's will the impression is made that shortly before extinction the Paleozoic brachiopods once more attained a great development. Probably, however, on account of this accelerated development, they held in themselves the cause for their early extinction, as shown by the aberrant, weak, and possibly even degenerate forms." It is one of the remarkable occurrences that at the close of the Paleozoic, in different stocks of the Strophomenacea, aberrant forms became numerous. These genera are *Keyserlingina*, *Oldhamina*, *Lyttonia*, *Lorzyella*, *Tegulifera*, *Richthofenia*, *Proboscidella*, and *Scacchinella*.
C. S.

7. *The Tower of Pelée: New Studies of the Great Volcano of Martinique*; by ANGELO HEILPRIN. Pp. 62, 4to with xxii pls. Philadelphia, 1904 (J. B. Lippincott & Co.).—The results of the studies by the author of the volcanic phenomena of Martinique have already been partly made known in several valuable papers which he has published. The present work contains much interesting descriptive matter and some important suggestions concerning the nature and cause of volcanic action, but its chief interest lies in the description and explanation of the remarkable monolith which rose from the top of Mont Pelée until nearly a thousand feet in height. In spite of repeated shattering and breaking it maintained by constant upward growth a great height for many months before it disappeared. This tower of rock Professor Heilprin regards as the solidified plug of lava filling the conduit of the volcano from a previous active stage which was driven up and out by the renewal of volcanic activity which has recently taken place, and not as the lava of the present epoch, cooling and solidifying as it is forced upward. The facts and arguments favoring this view are presented in detail, since the latter idea has been held by other investigators. The volume is an important and timely contribu-

tion to volcanology and is embellished with many beautiful half-tone plates, reproductions of the author's photographs. L. V. P.

8. *Die Jüngeren Gesteine der Ecuatorianischen Ost-Cordillere*, von F. TANNHÄUSER. Wilhelm Reiss, Ecuador, 1870-1874, Petrograph. Untersuch. II, Lief. II, pp. 119-186, 4°, 1904 Berlin.—This is a continuation of the investigation by Reiss of the rocks collected by him in the Andes; this investigation has now been carried on for many years in the mineralogical institute of the University of Berlin under the direction of Professor Klein, as noticed in previous issues of this Journal.

The rocks described are from the Cordillera de Pillaro as far as Sangay, from Azuay and from a part of the Cuenca basin, and comprise the lavas of the great volcanoes of Tunguragua, Altar, Sangay and Azuay. They are nearly all varieties of dacites and andesites whose petrographic characters are given in detail accompanied by a number of analyses. L. V. P.

9. *Die Älteren Gesteine der Ecuatorianischen Ost-Cordillere*, von F. VON WOLFF. Ibidem Lief. III, pp. 189-304, 1904.—In the work mentioned in the foregoing notice only the geologically recent lavas are considered. The petrographic investigation of the region named above is completed in the present memoir, which gives the results of researches made on the older rocks. These comprise gneisses, amphibole schists, diabases in various stages of dynamic metamorphism, mica schists, granites, gabbros, porphyries of various kinds, etc. These have been carefully studied and correlated and in a number of cases analyzed. These two works add much to our knowledge of Andean rocks and petrology. L. V. P.

10. *Ueber die Chemische Zusammensetzung der Eruptivgesteine in den Gebieten von Predazzo und Monzoni*, von J. ROMBERG. Anhang. Abhandl. d. K. Preuss. Ak. Wiss. Jahr, 1904, pp. 135, 4°, Berlin.—In this work the author, in addition to giving a number of new analyses of the rocks of this classic locality, which have been made in connection with his researches by Drs. M. DITTRICH and R. POHL, has assembled all those previously made by other investigators. They are arranged and discussed according to the chemical classification proposed by Osann. The recent work of other geologists in this region is also taken up and critically examined and many dissenting opinions expressed. The new analyses have evidently been well and carefully executed and add much information to our knowledge of this complex and interesting group of igneous rocks. L. V. P.

11. *Heptorit, ein-haun-monchiquit aus dem Siebengebirge am Rhein*, von K. BUSZ. Neues Jahrb. f. Min., Bd. II, 1904, pp. 86-92.—This new variety of monchiquite occurs as a narrow dike on the boundary between trachyte and Devonian graywackes and in the hand specimen appears like a fine-grained basalt. The microscope shows it to consist of basaltic augite, a relatively large amount of brown hornblende in fine needles and well crystallized violet-blue haunynite. These minerals lie in a colorless

base which is assumed to be glass ; whether it may not be wholly or in part analcite is not mentioned. Occasional laths of labradorite also occur and in places the rock holds the large masses of olivine often seen in basaltic rocks. An analysis gave the following results :

SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	CaO	MgO	Na ₂ O								
48.92	1.78	17.62	4.05	3.94	13.07	8.16	2.84								
								K ₂ O	H ₂ O	SO ₂	P ₂ O ₅	Cl	Total		
								1.83	2.82	0.47	0.15	0.22	= 100.37		

This appears to be a well-defined type of this small but interesting group of igneous rocks. The name is the translation into Greek of the Siebengebirge where it occurs. L. V. P.

12. *Die Kristallinen Schiefer, I, Allgemeiner Theil*, von U. GRUBENMANN. Pp. 101, 8vo, 2 pls. 1904, Berlin (Bornträger Pub.)—The author states that this work, which is a summation of his lecture course upon this subject, is an attempt to explain in accordance with physical and chemical principles the origin and characteristic properties of the crystalline schists. He begins with a description of the material from which the schists are formed, giving the origin and characters of the sedimentary and igneous rocks, so far as these pertain to the subject. Next the various factors of metamorphism are dealt with, the effects of solutions, of high temperatures, of pressure, etc. After this the results of these agencies in the production of different minerals, structures, textures, etc., are discussed and the work concludes with a short, general account of the geological occurrence of the crystalline schists. It is clearly and simply written and the student and teacher of petrography will find much in it that is interesting and suggestive. It is inferred from the scope and title of the book that it is only the introductory portion of a larger descriptive work. L. V. P.

13. *Yttrium and Ytterbium in Fluorite*.—W. J. HUMPHREYS, as the result of a spectroscopic examination of samples of fluorite from many localities in all parts of the world, shows that the rare element yttrium is distinctly present in most cases while a considerable number contain also ytterbium. The specimens found to be richest in these elements were from Amelia Court House, Virginia, Llano County, Texas and Corocoro, Bolivia. The two localities first mentioned afford a number of rare mineral species which were also found to contain yttrium and often in addition ytterbium. It is interesting to note that the three samples mentioned proved to be exceptionally sensitive to the effect of heat in producing phosphorescence ; as noted by the author some years since, a fluorite from Amelia Court House became luminous simply from being held in the hand for a few minutes.—*Astrophys. Journal*, xx, 266.

14. *Hamlinite from Brazil*.—The rare mineral species hamlinite, thus far only known from Maine, as described by Penfield, has been identified by Hussak in the diamond-bearing sands of the Serra de Congonhas, Diamantina, Brazil. It occurs sparingly

in colorless to rose-red or yellow crystal and cleavage fragments: the faces *c*, *r* and *f* were identified and the angles found to agree with the measurements of Penfield. The specific gravity is 3.254 to 3.281. A qualitative examination by Florence proved the Brazilian mineral to be a hydrophosphate of aluminium and strontium without barium or fluorine, but probably containing a small amount (2 p. c.) of alkalis.—*Ann. Nat. Hofmuseums*, xix, 93, 1904.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Publications of the Yale Observatory*.—The Yale Observatory has recently issued a Report of the Director, Dr. W. L. Elkin, for the years 1900–1904. In regard to the work of 1903–1904, he states: “During the past year the heliometer has been in active operation, Dr. Chase having devoted himself with great energy and self-sacrifice to the completion of the stellar parallax research we have been engaged upon for the past ten years. This now may be said to have finally reached a point where the observations may be suspended and our energies entirely given to their reduction. Mr. Smith has completed the new series on the parallax of Arcturus and has begun a series on the parallax of the Pleiades.

The meteor apparatus was put in use during the November epoch and a few trails secured. Dr. Max Wolf of Heidelberg, Germany, has kindly forwarded to us his meteor photographic trails of the Perseid epoch and those which seem to be true Perseids have been measured by Miss Palmer. Miss Palmer and Miss Newton are still employed on the index catalogue to the Bonn Durchmusterung. The time service has been maintained efficiently by Messrs. Chase and Smith.”

The concluding portion of Volume I of the *Transactions* has also been published. This includes the Preface and Parts VII and VIII, pp. 335–390. These parts are devoted to a Revision of the first Yale triangulation of the principal stars in the group of the Pleiades by Dr. W. L. Elkin; and a second Determination of the relative position of the principal stars in the group of the Pleiades by Mason F. Smith.

2. *Publications of the Yerkes Observatory, Vol. II, 1903*. Chicago, 1904 (University of Chicago Press).—This volume, also issued as Vol. VIII of the first Series of the Decennial Publications of the University, contains a series of seven articles, on work done at the Yerkes Observatory; their titles are as follows: Measures of double stars in 1900 and 1901, by S. W. Burnham; micrometrical observations of Eros during the opposition of 1900–1901, by E. E. Barnard; recent rigorous methods of treating problems in celestial mechanics, by F. R. Moulton; radial velocities of twenty stars having spectra of the Orion type, by E. B. Frost; spectra of stars of Secchi's 4th type, by G. E. Hale, F. Ellerman and J. A. Parkhurst; astronomical photography with

the forty-inch refractor and two-foot reflector, by G. W. Ritchey, accompanied by 26 plates, giving beautiful photographs of the moon's surface, star clusters, nebulae, and other points; and lastly, the orbit of the minor planet (334) by Kurt Laves.

3. *How to Know the Starry Heavens, a Study of Suns and Worlds*; by EDWARD IRVING. Pp. xvi, 313, with charts, colored plates, diagrams, etc. New York, 1904 (Frederick A. Stokes Co.).

—The present volume is one of a series planned by the author which are to deal with the sciences of Astronomy, Geology, Biology and Sociology. It is a very liberally illustrated account of the celestial universe, with the subjects presented in clear, popular, and often colloquial style, which must certainly appeal to the class of readers for which it is intended. Some of the word-illustrations introduced are novel and ingenious, and will help to an understanding of a somewhat difficult subject. The next volume to appear will deal with the earth, from its nebulous birth to the advent of man, and will be entitled: "How to Know the Earth's History."

4. *The Jefferis Mineral Collection*.—It is announced that the Carnegie Museum, Pittsburg, Pa., has purchased the Jefferis collection of minerals; it is to be known in perpetuity as "The W. W. Jefferis Mineral Collection of the Carnegie Museum." It owes its existence to the active work and liberal expenditure by Mr. Jefferis begun some seventy years ago, and now ranks as one of the finest private collections of minerals in America. Living in West Chester, Chester county, Pa., he had unusual opportunities of collecting choice specimens from the ancient gneisses, serpentines and limestones, as well as from the trap rocks of eastern Pennsylvania, New Jersey and New York. He also visited northern New York, Canada and Europe; and carried on extensive exchanges with other collectors all over the world.

Mr. Jefferis, although primarily a collector, was also a discoverer and contributor to science. A number of new minerals were discovered by him and in addition he aided largely in extending the distribution of known minerals and in furnishing material for the reëxamination of old or poorly known ones. Dana drew largely from Mr. Jefferis' notes and specimens, some of which were figured in his "System of Mineralogy"; Gent's "Mineralogy of Pennsylvania" was also indebted to Mr. Jefferis' labors in the field.

5. *The Chemical Engineer*.—A new monthly journal of practical, applied and analytical chemistry was started in November, 1904, under the above title. It is published by The Chemical Engineer Company, Allentown, Pa., at \$3 a year. The first number contains articles on the Valuation of Coal for Steaming Purposes, on Tests for Wood Paving, with others on subjects less directly technical.

OBITUARY.

DR. BENJAMIN W. FRAZIER, Professor of Mineralogy and Metallurgy at Lehigh University, Bethlehem, Penn., died on January 4 at the age of sixty-three years.

THE AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XIV.—*On the Optical Constants of the Human Eye for different Colors*; by CHARLES S. HASTINGS.

A COMPLETE determination of the optical constants of the human eye for all conditions of accommodation and for all colors is yet wanting in the literature of physiological optics. Indeed, the only addition to the knowledge possessed by Helmholtz and published in his famous *Physiologische Optik* nearly forty years ago, consists in a slight change in his assumptions as to the dimensions of the schematic eye and a calculation of its cardinal points when accommodated for a near object.*

A necessary use for a larger knowledge recalled to my mind a series of observations made several years ago for a different purpose, but which would clearly yield the required information. These observations are contained in the following table, in which the first column contains the Fraunhofer line which defines the kind of light observed; the columns headed N and F, respectively, the nearest and farthest distances, in inches, at which I could see distinctly the spectral line; the column under $-c$ is the mean of the reciprocals of N and F, and the last column the difference of these reciprocals.

Line	N	1/N	F	1/F	$-c$	1/A
A	15.75	.06349	18.00	.05556	.05952	.00793
D	12.60	.07937	13.80	.07246	.07592	.00691
F	10.40	.09615	11.25	.08889	.09252	.00726
G	8.60	.11628	9.50	.10526	.11072	.01102
H.K	7.25	.13793	8.50	.11765	.12779	[.02028]

* It should be noted that W. Einthoven computed the constants for two different refrangibilities, namely, for that of the Fraunhofer D and F lines, for a schematic eye adjusted for great distance; but his assumption that the dispersive power is very nearly as great as that of dense flint glass makes them unavailable. A possible misspelling renders two of the constants erroneous. See *Pflüger Archiv. f. Physiol.*, lxii, 166.

AM. JOUR. SCI.—FOURTH SERIES, VOL. XIX, No. 111.—MARCH, 1905.

The last column headed $1/A$ is the well known Donders constant of accommodation. This should be nearly constant for all wave-lengths of light. Neglecting the last value, which is sure to be greatly in excess on account of unavoidable errors due to fluorescence of media of the eye impairing the precision of vision in this region of the spectrum, the mean value of the accommodation constant is $\cdot00825/1$ in. With this value of the constant of accommodation and an assumed accuracy of the values of c , the calculated values of the far and near points are as follows:

	N'	F'
A	15.71	18.06
D	12.50	13.94
F	10.35	11.31
G	8.70	9.38
H.K	7.58	8.09

The errors implied in the observations of the extreme violet light are just such as we should expect from the imperfect vision in this region of the spectrum due to fluorescence. If we assume that the differences for the other wave-lengths are due to errors of observation only, we find that the probable error of a single measurement is ± 0.067 of an inch. As the measurements seem to have aimed at a precision not much greater than 0.1 of an inch, the accordance must be regarded as very satisfactory.

As to the precision with which c is determined, for it is the variation of this quantity which yields the physical constant desired, we have the following test. It is known that the media of the eye have dispersive powers not differing in kind from that of other colorless media, hence the differential refractive power of the eye ought to be expressible as a linear function of the indices of refraction of such substances, water for example. Thus, from the following data,

	$C_A - C$	$n - n_A$
A	$\cdot00000$	$\cdot00000$
D	$\cdot01640$	$\cdot00365$
F	$\cdot03300$	$\cdot00788$
G	$\cdot05125$	$\cdot01135$
H.K	$\cdot06827$	$\cdot01424$

I find,

$$c_A - c = (4.50 \pm .08) (n - n_A) / 1 \text{ inch.}$$

In this result the observation on extreme violet light is included. The general conclusion, when the centimeter is chosen as the unit of length, may be written

$$\delta c / \delta n = 1.77 / 1^{\text{cm}}$$

where δn indicates the variation of index of refraction of water.

The results given above must be regarded as very accurate for the myopic eye studied, but it is not quite obvious how they should be employed as a basis for estimating the dispersive power of the average human eye, which may be supposed to be accurately equivalent to the schematic eye described in Helmholtz.* It seems probable, however, that the assumption that such an eye would possess the same differential power for different wave-lengths of light will prove not far from the truth. Under these conditions, since it is known that the dispersive powers of the aqueous and vitreous humors are the same as that of water, it is possible to calculate the virtual dispersive power of the lens of the eye, and it is found that we must assume a dispersive power in the lens of the schematic eye about half way between that possessed by ordinary crown glass and by dense flint glass, or, quite accurately, that of turpentine. If it were supposed that the eye examined differed from the schematic eye only in having a thicker lens, this value would be somewhat smaller. A discussion of known facts bearing on this point will appear at the end of the article.

We are now in a position to calculate all the cardinal points of the schematic eye for all accommodations and for all wave-lengths, but as these values cannot be given as linear functions of the variables, it is more useful to arrange a sufficient number in tables so that any required value can be found by proper interpolation. As a basis of the computations I adopt, after Helmholtz, as the mean refractive index of the aqueous and vitreous humors, $n_s = 1.3365$, and as that of the lens, $n'_l = 1.4371$. Also, the radii of the cornea, the front surface of the lens, and the back surface, are, respectively, 0.728, 1.000, and 0.600 centimeters. Finally, the dispersive power of the two humors being equal to that of water, we have :

	A	B	C	D				
$n - n_s$	-.00558	-.00446	-.00370	-.00183				
			E	F	G	H		
			+.00045	+.00241	+.00590	+.00900		

while, to meet the measured chromatic error of the eye as determined above,

$$\delta n' / \delta n = 1.57.$$

With these data I have computed the following tables. The values of c' in both tables are the reciprocals of the distance

* See Helmholtz, *Physiologische Optik*, 2te Auflage s. 140.

TABLE I.

Curvature of incident wave-surface		$c' = \cdot 0000$	$c' = -0\cdot 0100$	$c' = -0\cdot 0330$	$c' = -0\cdot 0660$
		x	δx		
Curvature of the cornea	γ	1.2773			
Curvature of the first lens surface	γ'	1.0000	·1043	·3433	·6690
Curvature of the second lens surface	γ''	-1.6667	-.0239	-.0746	-.1520
Distance from vertex of cornea					
to first lens surface	d	·360	-.0060	-.0200	-.0400
to second lens surface	d'	·720			
to first principle focus	F_1	-1.3744	·0279	·0873	·1618
to second principle focus	F_2	2.2823	·0316	·0995	·1876
to first principle point	p_1	·1753	·0021	·0063	·0105
to second principle point	p_2	·2110	·0029	·0087	·0146
to first nodal point	n_1	·6969	-.0066	-.0210	-.0404
to second nodal point	n_2	·7325	-.0057	-.0186	-.0363

of distinct vision measured from the vertex of the cornea, which is taken as the origin of abscissas. The curvature of the cornea and the position of the second vertex of the lens are invariable.

For the chromatic differences for these constants we find the following table:

TABLE II.

x	$c' = \cdot 0000$	$c' = -\cdot 0100$	$c' = -\cdot 0330$	$c' = -\cdot 0660$
F_1	+5.660	+5.593	+5.464	+5.283
F_2	-5.504	-5.448	-5.342	-5.182
p_1	+0.175	+0.167	+0.158	+0.152
p_2	+0.335	+0.335	+0.331	+0.329
n_1	-0.179	-0.190	-0.211	-0.228
n_2	-0.019	-0.022	-0.038	-0.051

With these two tables it is easy to solve all problems connected with the purely optical properties of the schematic eye. We may, for example, employ them for comparing the performance of the model with any recorded observation on real eyes. Thus Helmholtz (page 158) states that for his eye the difference of accommodation for red (C) and violet (G) light was .0167, in the units employed in the tables, while Fraunhofer, who gave the first recorded measures involving this magnitude, found a value included between .0154 and .0205. The schematic eye as described in this paper demands .0167.

After all the above calculations were concluded I found a series of observations on his own eye by Max Wolf* which might have been used as well as the ones given above. His method was to observe a small globule of mercury, strongly

* Annalen d. Physik u. Chemie, xxxiii, 1888.

illuminated by sunlight, through a prismatic ocular and find the displacement of the globule when sharp definition of the spectrum was secured at different Fraunhofer lines. These observations are by no means easy, but they were carried out with remarkable skill so that the means of four series gave, after eliminating the dispersion due to the lens of the ocular, a result of exactly the same degree of precision as my own. Professor Wolf made no other use of his results than to prove that the human eye has notably greater dispersion than the reduced eye of Listing which is supposed to be made of pure water; but a reduction of them after the method in which mine were treated, when corrected for the slight degree of hypermetropy possessed by his eye, gave $\delta n' / \delta n$ equal to 1.523. In view of this fact I should prefer 1.54 as a definitive value were so small a change really worth while. Since the last value only differs from that employed by an amount equal to the probable error attaching to it, we may, I think, accept the results given above with considerable confidence.

Yale University, January, 1905.

ART. XV. — *Notice of the Discovery of a New Dike at Ithaca, N. Y.;** by V. H. BARNETT.

THE occurrence of several dikes of igneous rock cutting the Devonian shales and sandstones near Ithaca, N. Y., was recognized as early as 1842. Vanuxem† records in his report on the 3d District, the presence of four small dikes near Ludlowville. Other small dikes, which were discovered by students and professors of Cornell University, were described in a paper by Prof. Kemp,‡ in 1891. This paper is the latest published statement, so far as the writer knows, concerning the dikes at Ithaca. According to Prof. Kemp, four dikes were then known in the vicinity of Ithaca in addition to those recorded by Vanuxem. Kemp was able to relocate but two of Vanuxem's dikes, so that the total number then known was six.

During the past season the writer, engaged as a field assistant on the U. S. Geological Survey, discovered in connection with Dr. E. M. Kindle a number of hitherto unknown dikes in the vicinity of Ithaca. Most of these dikes, like those previously known at Ithaca, are thin sheets of peridotite generally from one to five inches in width. The total number of dikes now known to the writer near Ithaca exceed twenty-five.

One of the newly discovered dikes is of such unusual size for this region as to justify a brief preliminary notice. It is exposed in a small ravine on the west side of Lake Cayuga about one mile south of Glenwood. The dike is of light greenish gray color with numerous inclusions of shale and small limestone fragments. The latter are probably derived from the Tully limestone, which is some 450 feet below the outcrop. The numerous included fragments give the mass a breccia-like appearance. The direction is nearly north and south, but the contact is irregular and clearly shown on the east side, where the shale is considerably baked. On the west side the dike passes under a mass of drift so that the total width is not known. It is, however, not less than 25 feet thick. Another dike mass, 13 feet in width, lies 150 feet to the west of the one just described and is identical with it in appearance. The latter terminates abruptly on the west along a joint plane of the shale, and passes under the drift on the east. The relations of the two masses suggest that they may represent a single dike considerably more than 100 feet in width which pinches out both north and south. In Indian Creek, about three-quarters mile south of this outcrop, is a two foot dike and in Glenwood Creek, to the north, a dike eight feet wide occurs.

Ithaca, N. Y., January 24.

* Published by permission of the Director of the U. S. Geological Survey.

† Rep. 3d Dist. N. Y. State Geological Survey, p. 169.

‡ This Journal (3), vol. xlii, pp. 410-412, 1891.

ART. XVI.—*Dumortierite*; by WALDEMAR T. SCHALLER,
U. S. Geol. Survey.

THE following paper* is an excerpt of a paper on dumortierite to appear in a forthcoming bulletin of the U. S. Geol. Survey.

The description is mainly of the lavender California dumortierite and also of the Washington mineral. Several imperfect crystals—two from California, one from Arizona and three from New York—were found and some crystallographic data obtained.

The California dumortierite occurs in a dike, a few miles east of Dehesa, San Diego Co. The dike is in a disintegrated biotite granite and has a length of about 1000 feet with a thickness of from 30 to 40 feet and strikes S. 70° E., with a dip of 70° N. 20° E. The upper part of the dike is a fine-grained rock consisting of quartz and sillimanite, while the lower part is a coarse rock composed of quartz and dumortierite, the latter in radiating masses several centimeters thick. They show a transverse parting fairly well developed: the color of the mineral is lavender instead of blue; the pleochroism is from colorless to red-purple.

A number of thin sections of the dumortierite rock were prepared and studied with the following results.

Microscopically the minerals present in the lower part of the dike are seen to be dumortierite and quartz with muscovite and sillimanite in small quantities, together with accessory magnetite, titanite, rutile (?), apatite and zircon, with a number of small undetermined inclusions. The dumortierite occurs in irregular masses with ragged outline, and also in fan-shaped radiating masses sometimes of large size. Irregular broken fibrous masses also occur scattered through the slide. The quartz is allotriomorphic and is but slightly cracked. It is rather full of inclusions in places. With the exception of a little muscovite, there are no secondary minerals present.

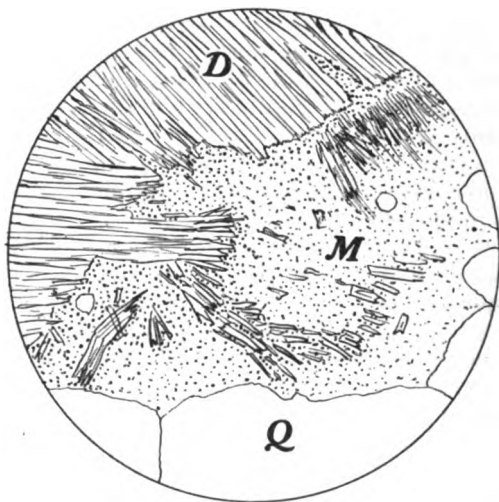
The common form for the dumortierite is the radiated fan-like masses that vary considerably in size. When the entire piece is larger than a quadrant, parts of the black cross (seen in spherulites) are seen when the nicols are crossed. These fan-shaped pieces are probably the results of an incomplete spherulitic growth. The most perfect one consisted of but half a circle. On certain parts no radiated fibers are detectable, the (prismatic) cleavage lines being perfectly parallel. Some of the pieces become decidedly fibrous towards the ends and the various individual fibers depart somewhat from true parallelism. In between these fibers, fine-grained aggregates of muscovite can often be seen.

* Published by permission of the Director of the U. S. Geol. Survey.

On a number of pieces a (secondary?) growth of fibers was seen which are probably in all cases dumortierite, as with high powers a faint pleochroism can be detected. They were at first thought to be sillimanite, but they agree in all their properties as far as can be determined with dumortierite. These fibers can be classed in two parts.

In the first part belong those which seem to have formed, as a secondary growth, on the main masses of dumortierite. The fibers branch out considerably and often form a radiating fringe around an entire section of the mineral. They penetrate the quartz grains and interstitial muscovite is absent. The line where they join on to the main mass of the mineral is usually

1



fairly well defined. In general, the fibers are normal to the edge of the main mass, but locally they vary considerably at times, especially where they form fan-like groups.

The second class is clearly a stage in the alteration of the dumortierite to muscovite. The solid mass of dumortierite becomes fibrous and, at the edge breaks up into small fibers which gradually become loose from the parent mass. The space where they formerly joined is now occupied by a granular mass of muscovite which also fills the spaces between the fibers. Gradually this process goes on till finally we have a large mass of granular muscovite, in which are imbedded a few fibrous prisms of the original mineral. Fig. 1 shows diagrammatically a stage in the process.

Basal sections present an entirely different appearance. The macropinacoidal cleavage, so well developed on the New York mineral, does not show on the sections of the California mineral.

The imperfect prismatic cleavage is present and divides the section up into a multitude of irregular bodies. Occasionally a short crack is observed which is parallel to the brachypinacoid, and it may be that the mineral possesses an imperfect interrupted brachypinacoidal cleavage.

The prismatic cleavage was found to be parallel to the prism (210). A large number of measurements gave as the angle (010): cleavage cracks 62° – 67° , averaging 64° – 65° . The angle (010): (120) is $65^{\circ} 23'$. The cleavage cracks are irregular and it was difficult to obtain any accurate measurements, but the ones made are sufficient to determine the cleavage. They were measured against the trace of the optic axial plane (= (010)).

Polysynthetic twinning lamellæ were observed a number of times and in one particular section (the same on which the prismatic cleavage was measured) were determinable to a certain extent. The alternate lamellæ extinguished together, the difference in angle of extinction of two adjacent lamellæ being 31° . The line joining these lamellæ is parallel to the cleavage or to the prism (210).

The pleochroism of the mineral is beautiful, especially if the section be not too thin. $c = a$ is colorless, $b = b$ is colorless to very faint pink, $a = c$ is deep red purple. None of the sections entirely possess the ordinary blue pleochroism. In some slides, however, there are certain small areas of varied and irregular shape which do show the ordinary pleochroism. These small blue areas in the rich red-purple background make a most beautiful combination. On some sections a large area will have a faint bluish purple color, as if intermediate between the deep blue and the red-purple.

The axial angle on the California dumortierite is small. The following measurements were made with the microscope and micrometer ocular and represent only approximate values.

$$2E_{Li} = 33^{\circ}$$

$$2E_{Na} = 37^{\circ}$$

$$2E_{Ca} = 42^{\circ}$$

The dispersion is $\rho < v$.

The dumortierite from Skamania Co., Washington, was first described by Ford.* Mr. Brereton, of Woodstock, Oregon, kindly sent the writer some specimens on which the following description is based.

The rock is a light-colored fine-grained one, composed of about equal parts of andalusite, quartz and muscovite (determined in thin section).

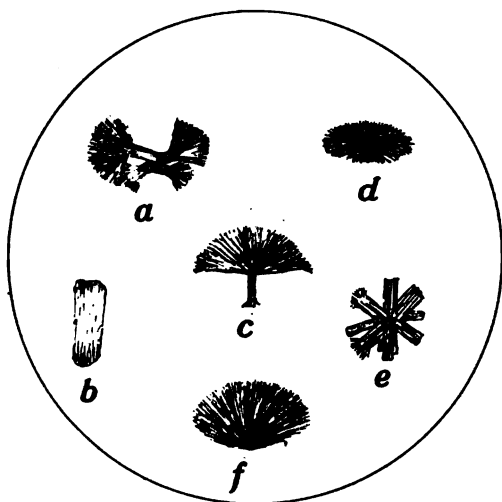
The dumortierite occurs in small spherulites scattered throughout the rock and occasionally bunched together to form a large patch of blue. On an average they reach a diameter of from $\frac{1}{4}$ to 1^{mm} . Their shape, while in general circular, is often

* This Journal (4), xiv, 426.

elliptical and may become very irregular in places. The spherulites consist of fibers radially arranged and show all the optical phenomena of "spherulites." The dumortierite has parallel extinction and its birefringence is somewhat higher than that of the quartz and also slightly more than that of the andalusite, though the difference between that of the latter two minerals is very small.

The intensity of the pleochroism of the dumortierite varies so that in some spherules there are concentric bands of fibers varying greatly in the intensity of their color. Some are almost colorless, and it was at first thought they might be par-

2



allel growths of andalusite with the dumortierite, but such a conclusion could not be verified.

The fibers are not always perfectly radial. They are at times gathered into "brushes" and a number of these put together may form a spherulite. The fibers are thus more thickly crowded in places than elsewhere, and this frequently results in intensifying the pleochroism, so that in some spherulites there are numerous blotches of blue much deeper colored than the rest. Muscovite is frequently abundant in a spherulite, being formed between the fibers, and is probably an alteration product of the dumortierite. Frequently a mass of dumortierite will be almost completely changed to mica, leaving but small fragments of the original mineral behind.

The fibers of dumortierite, while usually arranged radially, sometimes assume different shapes, and some of the masses of dumortierite seen under the microscope are reproduced in fig. 2.

Fig. 2 shows variations from typical spherulitic form that the fibers of dumortierite assume. *a* is four prisms irregularly joined at the center, the ends spreading out into "brushes" of fine fibers. This form is fairly abundant. *b* forms a prismatic portion becoming fibrous at both ends, and while common in the New York, Arizona, and California occurrences is a rare type for Washington dumortierite. *c* forms a sort of fan and is composed of several "brushes" joined together. It is a common type. *d* is an elliptical spherulite. *e* is a mass of prisms such as *b* but not spreading out as *a* does. It is of rarer occurrence. *f* is a bunch of radial fibers with no prismatic stem as in *c*. It is fairly common.

Crystallographic.

The mineral is orthorhombic and from the various measurements the following axial elements have been calculated:

$$a = .8897$$

$$c = .6871$$

The crystals were measured with the two-circle goniometer, and the values for p_0 and q_0 , from which the above ratios are obtained, are:

$$p_0 = .7723$$

$$q_0 = .6871$$

The forms observed are as follows:

$$b = 0 \infty = 010$$

$$g = \frac{3}{2} \infty = 320$$

$$a = \infty 0 = 100$$

$$n = 2 \infty = 210$$

$$l = \infty 2 = 120$$

$$d = \frac{1}{2} 0 = 102$$

$$m = \infty = 110$$

$$v = \frac{3}{2} 0 = 203$$

Besides these forms, reflections were obtained from several other minute faces, but they were so minute and the reflections so poor that their validity is very questionable and they are omitted from the foregoing list. The average of the measured angles compared with the calculated values are shown in the following table:

Letter.	Symbol.	Measured.		Calculated.	
		ϕ	ρ	ϕ	ρ
<i>b</i>	$0 \infty = 010$	$0^\circ 00'$	$90^\circ 90'$	$0^\circ 00'$	$90^\circ 00'$
<i>a</i>	$\infty 0 = 100$	91 23	"	90 00	"
<i>l</i>	$\infty 2 = 120$	29 19	"	29 20	"
<i>m</i>	$\infty = 110$	49 01	"	48 20	"
<i>g</i>	$\frac{3}{2} \infty = 320$	59 49	"	59 19	"
<i>n</i>	$2 \infty = 210$	65 23	"	66 01	"
<i>d</i>	$\frac{1}{2} 0 = 102$	91 21	21 46	90 00	21 07
<i>v</i>	$\frac{3}{2} 0 = 203$	87 39	26 58	"	27 14

The brachypinacoid is present on four crystals, usually as broad faces. Some give relatively good reflections.

The macropinacoid occurs on all the crystals except the one from Arizona. The reflections were poor but serve to identify the form. The ϕ angles measured are as follows:

90° 02' (Cal.)	Calc. 90° 00'
93 46 "	
90 00 "	
92 57 (N. Y.)	
91 15 "	
90 16 "	

The brachyprism $l = \infty 2 = 120$ occurs on four crystals, giving fair reflections.

Meas. (ϕ) 30° 00' (Cal.)	Calc. (ϕ) 29° 20'
28 00 "	
29 22 "	
29 34 (N. Y.)	
29 39 "	

The unit prism is poorly developed on the California crystals, being present but once as a narrow face giving a poor reflection. On the Arizona crystal it occurs twice as broad faces.

Meas. (ϕ) 48° 52' (Cal.)	Calc. (ϕ) 48° 20'
49 16 (Ariz.)	

The macropism $g = \frac{2}{3} \infty = 320$ is present several times on all the crystals except the one from Arizona. The measured angles vary somewhat.

Meas. (ϕ) 58° 55' (Cal.)	Calc. (ϕ) 59° 19'
59 42 "	
60 36 "	
59 38 "	
59 23 "	
60 14 "	
59 04 (N. Y.)	
60 07 "	
59 25 "	
60 23 "	
60 31 "	

The macropism $n = 2 \infty = 210$ is present four times. The reflections were fair.

Meas. (ϕ) 65° 26' (Cal.)	Calc. (ϕ) 66° 01'
65 35 "	
65 19 "	
65 12 "	

The macrodome $d = \frac{1}{2} 0 = 102$ is present once on the Arizona crystal. The reflections were not very good. The dome $v = \frac{1}{3} 0 = 203$ is present on one of the California crystals. The

face is exceedingly minute and is not shown in the drawing, fig. 3, A, and the reflection was poor.

On crystal No. 4 (N. Y.) were observed two very small faces, giving poor reflections.

$$\begin{array}{lcl}
 & \phi & \rho \\
 (1) \left\{ \begin{array}{l} 83^{\circ} 46' \\ 83 \ 16 \end{array} \right. & & \begin{array}{l} 17^{\circ} 54' \\ 17 \ 44 \end{array} \\
 (2) \left\{ \begin{array}{l} 80 \ 19 \\ 84 \ 17 \end{array} \right. & & \begin{array}{l} 16 \ 50 \\ 17 \ 28 \end{array}
 \end{array}$$

These agree approximately with the symbol $\{8.1.20\}$ or considering the form vicinal to a dome, to $\{205\}$.

The following table gives the calculation of the forms of dumortierite based on the elements given in this paper. The table corresponds to those given in Goldschmidt's Winkel-tabellen.

$a = .8897$	$lga = 9.94924$	$lga_s = 0.11202$	$lgb_s = 9.88779$	$a_s = 1.2943$	$p_s = .7723$
$c = .6871$	$lgc = 9.83702$	$lgb_s = 0.16298$	$lgq_s = 9.83702$	$b_s = 1.4554$	$q_s = .6871$

No.	Letter	Sym. Gdt	Sym. Miller	ϕ	ρ	ξ_s	η_s	ξ	n	χ (Prism) $x:y$	ψ	$d =$ $tg \rho$
1	b	0∞	010	$0^{\circ} 00'$	$90^{\circ} 00'$	$0^{\circ} 00'$	$90^{\circ} 00'$	$0^{\circ} 00'$	$90^{\circ} 00'$	0	∞	∞
2	a	$\infty 0$	100	$90^{\circ} 00'$	"	$90^{\circ} 00'$	$0^{\circ} 00'$	$90^{\circ} 00'$	$0^{\circ} 00'$	∞	0	"
3	l	$\infty 2$	120	$29^{\circ} 07'$	"	"	$90^{\circ} 00'$	$29^{\circ} 07'$	$60^{\circ} 53'$	.5570	∞	"
4	m	∞	110	$49^{\circ} 01'$	"	"	"	$49^{\circ} 01'$	$40^{\circ} 59'$	1.1510	"	"
5	g	$\frac{3}{2} \infty$	320	$59^{\circ} 47'$	"	"	"	$59^{\circ} 47'$	$30^{\circ} 13'$	1.7170	"	"
6	n	2∞	210	$65^{\circ} 23'$	"	"	"	$65^{\circ} 23'$	$24^{\circ} 37'$	2.1825	"	"
7	d	$\frac{1}{2} 0$	102	$90^{\circ} 00'$	$21^{\circ} 07'$	$21^{\circ} 07'$	$0^{\circ} 00'$	$21^{\circ} 07'$	$0^{\circ} 00'$	.3862	0	.3862
8	v	$\frac{3}{2} 0$	203	"	$27^{\circ} 14'$	$27^{\circ} 14'$	"	$27^{\circ} 14'$	"	.5147	0	.5147

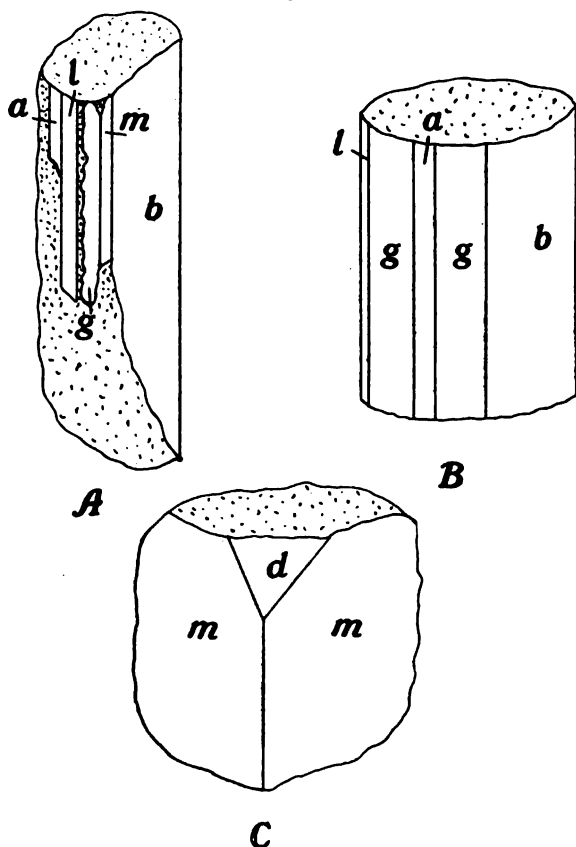
The combination seen on the six crystals measured are :

No. 1	Cal.	b,	a,	l,	m,	g,	n,	—,	v,
" 2	"	b,	a,	l,	—,	g,	n,	—,	—,
" 3	Ariz.	—,	—,	—,	m,	—,	—,	d,	—,
" 4	N. Y.	b,	a,	—,	—,	g,	—,	—,	—,
" 5	"	b,	a,	l,	—,	g,	—,	—,	—,
" 6	"	—,	a,	l,	—,	g,	—,	—,	—,

Fig. 3 shows three of the crystals.

A is from California, size $1^{\text{mm}} \times \frac{1}{4}^{\text{mm}}$.
 B " New York, about $1^{\text{mm}} \times \frac{1}{2}^{\text{mm}}$.
 C " Arizona, about $1^{\text{mm}} \times 1^{\text{mm}}$.

3



The minerals andalusite, sillimanite, staurolite and dumortierite possess certain properties that are very similar. They are all orthorhombic, their axial ratios are similar, their principal constituents are silica and alumina, and in many ways these minerals can well be grouped together. A comparison of their axial ratios is given below :

	<i>a</i>	<i>c</i>
Andalusite	·9861	·7025
Sillimanite	·970	?
Staurolite	·9795	·6942
Dumortierite	·8897	·6871

For staurolite the values are taken from Goldschmidt's Winkel-tabellen with the a and c axes interchanged.

There was some question in the writer's mind as to whether the orientation chosen was the best or whether the present prism {210} had not better be made the unit prism. The cleavage is parallel to this prism and the twinning also bears some relation to this form. Moreover, the ratio above given for staurolite, though adopted by Goldschmidt, is not, in the writer's opinion, the best one for that mineral. The one given by Dana, who makes the a axis just half as long, would be the better one. The common form of staurolite is prismatic with a prismatic angle of $50^{\circ} 40'$ (Dana).

For andalusite, on the other hand, the prismatic angle is $89^{\circ} 12'$ and the a axis should be .9861 as given. Should dumortierite be classed crystallographically with staurolite or with andalusite? Unfortunately, the evidence is almost too meager to decide this question. On the California crystals the unit prism is poorly developed, and entirely absent from the New York crystals, the strongest form next to the brachypinacoid being the prism {320}. The prismatic cleavage is parallel to {210}, and making the cleavage form the unit prism the a axis should be given half its present value. On the other hand, the Arizona crystal is of the typical andalusite habit and making the prism the unit one, we obtain the axes as here given. Giving staurolite the (approximate) axes as andalusite and dumortierite, the prismatic cleavage is parallel to the same form as in dumortierite, namely {210}.

Chemical.

In 1881, after the first announcement of the discovery of the mineral had been made by Gonnard, Damour gave the following analysis of the mineral:

SiO ₂	29.85
Al ₂ O ₃	66.02
Fe ₂ O ₃	1.01
MgO .....	.45
Ign.	2.25

99.58

Sp. gr. 3.36

From this analysis the formula $4Al_2O_3 \cdot 3SiO_2$ was calculated. Damour did not suspect the presence of boric acid in the mineral and what was weighed as alumina probably contained several per cent B_2O_3 . In 1887 Riggs gave an analysis of the New York mineral in which he found 4 per cent B_2O_3 . Two years later Whitfield gave several analyses of American dumortierite, all showing the presence of B_2O_3 . In 1899 Linck gave some observations on the mineral, including an analysis by

W. Schimpff showing a strong test for boric acid. In 1902 Ford gave us three analyses of American dumortierite and also mentioned two new localities. During the winter of 1903-4 the writer made an analysis of the California dumortierite collected by himself during the previous summer. An analysis was also made at the same time of the Washington dumortierite kindly furnished by Mr. Brereton.

Believing that one good analysis is better than several poorer ones for the exact determination of the formula of the mineral, there will be presented an analysis of the California dumortierite made by the writer. From this a formula has been calculated for the mineral, and it will be shown how the other analyses agree with this proposed formula. Before giving the results a few preliminary words will not be out of place.

An analysis of dumortierite is a difficult operation. The small amount of silica makes it difficult to get a good fusion. On preliminary trials on an analysis of the California dumortierite, it was found that what was weighed as silica, in the regular course of the analysis, contained more or less of the undecomposed mineral. Results of about 30 to 32 per cent were obtained. This is, of course, on the uncorrected silica. It was found that a second fusion of the supposed silica was not only very beneficial but also necessary. What was then weighed as silica contained but little residue. The handling of so large an amount of alumina is very cumbersome and an accurate determination of the alumina (plus iron and other oxides here precipitated) is difficult. The boric acid determination is a tedious and difficult one. The accurate determination of the water, which is only given off at a high temperature, is also not easy. One can thus see that an analysis of such a mineral is a difficult operation and that a greater allowance must be made than for most silicate mineral analyses.

The specimen analyzed was selected in the field, an exceedingly pure piece weighing about ten grams being selected. The specific gravity of this piece was taken by suspension in water, giving 3.306. This was broken into small pieces and carefully examined for muscovite, quartz, or other minerals. Sections of the mineral showed that the dumortierite was free from any inclusions. No grains of any titanium mineral abundant in the quartz could be detected. When the mineral was powdered it was treated with heavy solution of sp. gr. 3.10, and a minute amount of mineral (muscovite?) stayed on top and was removed. The separation was repeated several times, the powder dried at 100° and carefully examined under the microscope for impurities. None were found. The mineral was unquestionably pure.

The general analytical methods used were those pursued in the Survey laboratory for silicate analysis with a few modifications. The mineral was fused with sodium carbonate, the

silica separated and refused with sodium carbonate. The silica was filtered off and weighed and treated with HF, which left some residue. The alumina (plus iron and titanium) was precipitated three times to be sure of removing all of the sodium salts. It was ignited and weighed with the silica residue, fused with sodium bisulphate, some silica recovered, the iron reduced and determined by titration and the titanium determined colorimetrically. The presence of titanium was suspected from the color of the pleochroism of the mineral. The boric acid was determined by the Gooch method, using all of the known precautions. The mineral was twice fused with sodium carbonate and the boric acid was finally weighed as lime borate. The water was collected in a calcium chloride tube, the mineral being heated in a Gooch tubulated crucible in the usual manner. A blank determination was run before and after each water determination and a small correction applied. All possible precautions were taken throughout the analysis, which was made in duplicate. The results are:

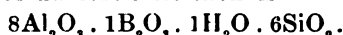
	1	2	Average.
SiO ₂	28.58	28.78	28.68
Al ₂ O ₃	63.31	63.30	63.31
Ti ₂ O ₃	1.49	1.40	1.45
Fe ₂ O ₃ .....	.21	.25	.23
H ₂ O	1.53	1.51	1.52
B ₂ O ₃	5.21	5.53	5.37
	<hr/> 100.33	<hr/> 100.77	<hr/> 100.56

The titanium is regarded as present as Ti₂O₃, replacing the alumina.

Combining the alumina, titanium and iron, the following ratios are obtained:

SiO ₂	5.94	or	6
Al ₂ O ₃	8.00		8
B ₂ O ₃	1.06		1
H ₂ O .....	.96		1

The formula for dumortierite then is



It has not been proven that either boric acid and alumina or boric acid and hydroxyl may mutually replace each other in minerals as fluorine and hydroxyl are known to do. There is then no reason that the writer can see why the alumina, boric acid and water in dumortierite should not be present in fixed quantities; that the variations shown in analyses are not due to "isomorphous replacements" but to inaccuracy of analyses or impure material.

Having established the above formula from the analysis, let us see how close the other analyses conform to the formula.

The best series of analyses is that by Ford from three American localities. His first analyses of the Arizona mineral are :

	1	2	3	Average.
SiO ₂	30.00	29.66	29.91	29.86
Al ₂ O ₃	63.20	63.74	63.76	63.56
Fe ₂ O ₃ .....	.23	.23		.23
B ₂ O ₃	5.47	5.06		5.26
H ₂ O	1.45	1.38		1.41

100.32

The ratios calculated from the average analysis gives :

SiO ₂	6.29	or	6 × 1.05
Al ₂ O ₃	7.94		8 × .99
B ₂ O ₃ .....	.96		1 × .96
H ₂ O	1.00		1 × 1.00

The agreement with the proposed formula is perfect.

His second analysis, that of the California mineral, shows slight variations from the results obtained by the writer. The presence of titanium was not determined. His analysis is :

		Ratios.	
SiO ₂	30.58	6.17	or 6 × 1.03
Al ₂ O ₃	61.83	7.40	8 × .93
Fe ₂ O ₃ .....	.36		
B ₂ O ₃	5.93		
H ₂ O	2.14	1.45	1 × 1.45

100.84

The ratios agree well with the new formula except for the water content. Remembering, however, that the amount of water present is very small and that a difference of .10 per cent would make a large difference in the ratios, that Ford determined his water by igniting the mineral with lime, thus not weighing the water directly, and that the writer obtained only 1.52 per cent on the same mineral from the same locality, it seems much more preferable to regard the determination of the water in Ford's analysis as too high rather than to attempt an explanation of it by the assumption of "isomorphous replacement, etc."

Of the third analysis by Ford, of the New York mineral, he says : "It is fully realized that the results are not to be looked upon as being as exact as those of the other analyses." His analysis is :

		Ratios.	
SiO ₂	31.24	6.23	or 6 × 1.04
Al ₂ O ₃	61.26	7.23	8 × .90
Fe ₂ O ₃ .....	.10		
B ₂ O ₃	6.14	1.06	1 × 1.06
H ₂ O	2.09	1.40	1 × 1.40

100.83

Again assuming that his water content is somewhat high, the ratios agree well with the new formula.

This concludes the list of analyses of dumortierite which were made on pure material and with due knowledge of what was to be determined. A number of other analyses will now be given which serve in a general way for the determination of the composition of the mineral, but can not be relied on for exact results.

One, which has heretofore not been published, was made by the writer on the Washington dumortierite. About 200 grams of the rock was powdered and by repeated separation with heavy solutions about 4 grams of dumortierite were obtained. The sample was by no means pure. It was found impossible to remove all the andalusite, an unknown but small amount remaining. It was found during the course of the analysis that the sample also contained some titanite (leucoxene) and a very small amount of pyrite. The analysis was made with all the care possible and the following results were obtained :

		Ratios after deducing titanite.	
SO ₃	28.51	5.97	or 6 × .99
Al ₂ O ₃	59.75		
Fe ₂ O ₃	2.48	7.80	8 × .97
TiO ₂ .....	.95		
H ₂ O	2.12	1.53	1 × 1.53
B ₂ O ₃	5.54	1.03	1 × 1.03
CaO .....	.68		

100.03

Excepting for the high-water content, the analysis agrees very well with the formula. No allowance was made for the small amount of andalusite present, which would slightly alter the ratios.

There now remain the analyses of Whitfield and Riggs, of which but one is suitable for any calculation. The analyses are as follows, No. 1 being of the New York mineral, by Riggs, No. 2 of the New York, and Nos. 3 and 4 of the Arizona mineral, by Whitfield :

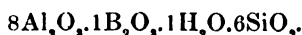
	1	2	3	4
SiO ₂	34.82	31.44	31.52	27.99
Al ₂ O ₃	55.30	68.91	63.66	64.49
MgO .....	.57	----	.52	tr.
K ₂ O	1.04	----	.11	----
Na ₂ O	1.76	----	.37	----
P ₂ O ₅	----	----	----	.20
B ₂ O ₃	4.07	tr.	2.62	4.95
Ign	2.96	----	1.34	1.72
	100.52	100.35	100.14	99.35

The ratios of the last analysis are :

SiO ₂	5.94	or	6 × .99
Al ₂ O ₃	8.09		8 × 1.01
B ₂ O ₃.....	.80		1 × .80
H ₂ O	1.22		1 × 1.22

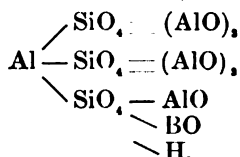
Approximately they agree with the formula.

The only question of which there seems to be any doubt is whether the water should be 1 or 1½ molecule. As, however, the best analyses show but 1 molecule and their evidence is considered as of much more value than a large number of inferior analyses, there is no question in the writer's mind but that the formula for dumortierite is

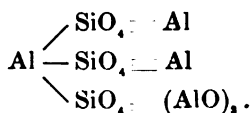


This may be written (SiO₂)₆Al(AlO)₇(BO)H, which is the same as the formula given by Groth except that for (BO) he puts (AlO). His formula is (SiO₂)₆Al(AlO)₇H.

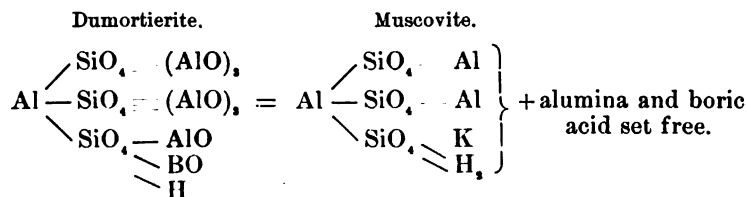
This may be written in the following form:



This formula is similar to that of andalusite, which is written



Dumortierite alters to muscovite. The change can be very well shown by these formulæ and seems to be entirely in accordance with the group of minerals to which it is related.



The writer's thanks are due to Mr. John A. Thoman of San Diego, the owner of the California dumortierite property, and to Mr. K. C. Naylor of San Diego, for many courtesies and favors.

ART. XVII.—*Crystallography of Lepidolite*; by WALDEMAR T. SCHALLER.

A GROUP of lepidolite crystals was collected by the writer in the summer of 1904, at a gem mine about four miles east of Ramona, on the stage road from Ramona to Julian, San Diego County, California. The mine was opened and worked for its gems, such as topaz, tourmaline, garnet, etc. With these are associated quartz, orthoclase in good crystals at times several feet long, and muscovite, and, rarely, lepidolite. The minerals in question all occur in the loose dirt, filling "pockets" in a pegmatite dike.

The specimen of lepidolite under consideration consists of a group of intergrown crystals which often reach a large size. The group itself is about 5^{cm} thick and the individual crystals measure about 1^{cm} across the base, though ones with a diameter of 2^{cm} are not rare. The crystals are also proportionally thick, the average being from 2 to 4^{mm}, though a few are somewhat thicker. They are transparent and of a very pale pink color, and, in the direction normal to the vertical axis and parallel to the base, of a slightly deeper tint. They fuse easily to a white enamel, coloring the flame an intense crimson. The side faces are usually plain, not rounded nor striated, and of a brilliant polish, giving excellent signals. It is, however, extremely difficult to secure a complete crystal from the group, owing to the perfect basal cleavage which will cause a crystal to split into a number of layers. This will also at times cause part of a crystal to become slightly displaced. In consequence of this difficulty, most of the crystals measured are only parts of the original crystals, and two such pieces measured as separate crystals may, in reality, be parts of one and the same crystal.

As may be expected, the crystals of lepidolite are similar to those of muscovite. The interfacial angles are nearly the same and the crystals are naturally referred to the same axes as muscovite. There are three marked differences between these crystals and those of muscovite: (1) the rarity of twins—only one being found in twenty-one crystals; (2) the absence of the characteristic face of muscovite, $M = \{221\}$; and (3) the presence of the a face $\{100\}$, occurring on ten out of twenty-one crystals. The crystals are not so striated as the green North Carolina muscovites for instance, and in many cases the faces yielded perfect signals.

The common forms are $c = \{001\}$, $b = \{010\}$, $a = \{100\}$, $e = \{023\}$, $o = \{112\}$, $u = \{\bar{1}11\}$, and $x = \{\bar{1}31\}$. Besides these, the following have been determined; $N = \{261\}$, $z = \{\bar{1}32\}$, 1

= {130}, and possibly several others, as $\{223\}$, $\{221\}$, $\{112\}$. Also a number of forms occurring for the most part as broad faces, giving good reflections but having anomalous indices and which need further study. The most frequent combination is *cboux*, after which comes *cbouxæa*. Whenever the angle (001): (010) could be accurately measured, it was found to be exactly $90^{\circ} 00'$ in every case, and the distribution of the faces also indicate monoclinic symmetry.

It was noticed that the angle between the same forms varied slightly on different crystals. The faces were smooth and highly polished and the angles could easily be measured with an error not greater than $1'$. It is suggested that this variation is real and is due to the fact that lepidolite is an isomorphous mixture of two end products, and as the ratio of these two products varies, the crystallographic and physical properties of the mineral also vary. Further study on the possible correlation of the various properties of the mineral is under way.

This lepidolite belongs to the "second class" of Tschermak or the "brachydiagonal class" of Scharizer, i. e., the axial plane is parallel to the clinopinacoid, and not normal to it. The trace of the axial plane was always parallel to one arm of the percussion figure. The above is only a brief preliminary statement; the detailed crystallography of the mineral will soon be published in a paper on the mineralogy of this entire field of lithium minerals in southern California. The writer's thanks are due Mr. Pan McIntosh, Jr., of Ramona, the owner of the mine.

Chemical Laboratory, U. S. Geological Survey.

ART. XVIII.—*Machine-Made Line Drawings for the Illustration of Scientific Papers*; by R. A. DALY.

It is safe to say that the majority of persons, who from time to time publish scientific papers, are seriously hampered in the preparation of text illustrations by the difficulty and expense entailed in the tedious drawing of map, section or diagram. Comparatively few authors can command the services of skilled draughtsmen or have themselves the requisite training to produce satisfactory line drawings. Yet the desirability of greatly increasing the proportion of such illustrations in the thousands of scientific articles published each year is manifest. That clearness, precision and conciseness in the exposition of a theme are generally enhanced by the use of abundant, appropriate diagrams is as evident as that the blackboard is the constant friend of the teacher of any branch of natural history or philosophy; the printed page needs its blackboard.

Ideally, the author should himself be able to make the original drawing quickly, neatly and artistically. The usual execution of drawing with the pen is, to the average author, discouragingly slow and expensive, not always neat, and still less often artistic. The following note relates to some experiments made to increase rapidity and neatness in the production of line drawings by the use of a machine. At the outset the experiments were, for obvious reasons, planned without any idea of rivalling the artistic work of the pen in a skilled hand. The aim has been to secure economy of time in execution and clear-cut precision of legend for the drawing. In both these respects enough success has been attained to warrant the recommendation of the machine method to geologists, geographers and others who desire to prepare useful text illustrations at a minimum cost of labor. Some experimental drawings were made and published in the *Bulletins of the Museum of Comparative Zoology at Harvard College*, vol. xxxviii, 1902, pls. 11, 12 and 13; in this *Journal*, August 1903, pp. 118 and 120; and in the *American Geologist*, August 1903, p. 66. The machine there used was an ordinary Underwood typewriter fitted with a black record silk ribbon.

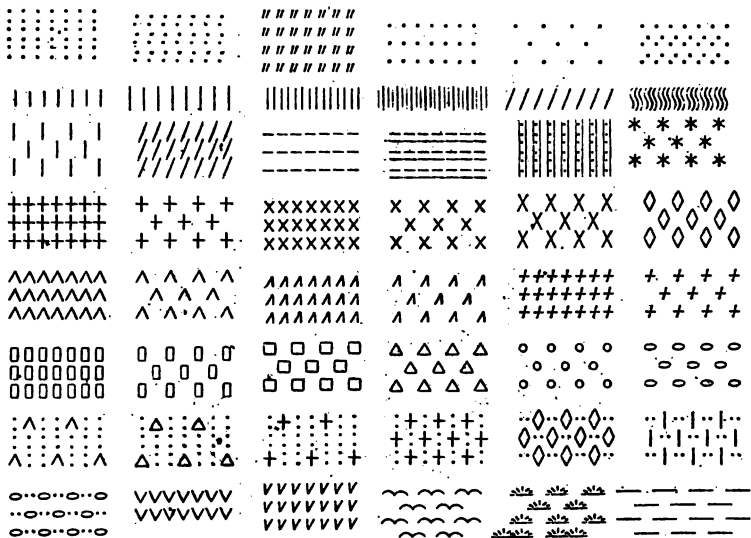
Recently the Hammond Typewriter Company of New York has constructed, for the Geological Survey Department of Canada, from the writer's specifications, a typewriter provided with a carbon ribbon and with ninety special characters designed for the preparation of line drawings to accompany geological and geographical papers. The same machine can be similarly used for statistical, engineering and other diagrams of a more or

less mechanical and simple composition. Of course this method should not wholly replace the use of the pen, even, for example, in the differentiation of areas in a geological map or section. The ultra mechanical look of the typewritten legend can often be pleasingly relieved by the easily and quickly applied cross-hatchings, etc., made with an ordinary drawing pen. In cor-

1

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z				
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z				
<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>	<i>m</i>	<i>n</i>	<i>o</i>	<i>p</i>	<i>q</i>	<i>r</i>	<i>s</i>	<i>t</i>	<i>u</i>	<i>v</i>	<i>w</i>	<i>x</i>	<i>y</i>	<i>z</i>				
1	2	3	4	5	6	7	8	9	0											1	2	3	4	5	6	7	8	9	0
Locality marks																		⊙	◦	X	†	□	▢	□	*				
Triangulation station etc																		↑	↑	△	△	▲	⊙						

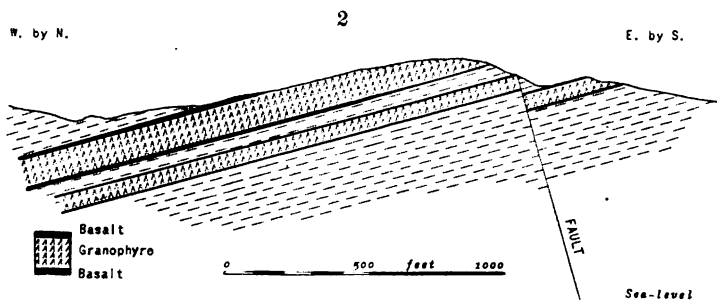
Samples of general purpose legends



plex diagrams free-hand work may generally be expected to supplement the work of the machine. The subject of each diagram should thus be studied with the end of securing suitable contrasts of legend along with the maximum economy of pen work; yet some pen work is almost always necessary.

The typewriter has its most general application in lettering, that most difficult element in line drawings. The machine used by the writer has the advantage of making it possible to employ a great range of type styles. With the carbon ribbon the writer has found that any one of the one hundred and

twenty-five shuttles made for such a machine (each shuttle bearing ninety characters and including the lettering for one of twenty-six different languages), will give an impression suitable for photographic reproduction. Each shuttle can be placed in the machine ready for work in a few seconds. The usual silk ribbon gives a "woolly" line, and is far less satisfactory than the carbon ribbon. A highly calendered and high-grade linen paper of a medium to heavy weight or a thin Bristol board may be recommended. Often more than one impression of the key is necessary to obtain the required depth of tint for photography; such repeated impressions can be made at great speed by employing a back spacing key. Care must be taken not to smudge the carbon of the completed printing.



The accompanying cuts serve to show something of the method as applied to geological diagrams. The diagram (fig. 1) of alphabets and legends has been reduced to four-fifths of its original diameter. The legends are intended to represent a few examples of those possible with the machine. They can be indefinitely increased in number and varied in design by the engraving of new characters on the shuttle, and by using various permutations and combinations of the existing characters. The section (fig. 2) is reduced to about one-half of its original diameter. It was copied from Harker's section of a composite triple sill published in "The Tertiary Igneous Rocks of Skye" (Memoir of the Geological Survey of the United Kingdom, 1904, p. 204). The result represents the saving of from seventy-five to ninety per cent of the time required by a draughtsman to duplicate the drawing.

It is to be understood, of course, in the preparation of a diagram that an outline drawing is first prepared, and that the spaces thus formed are filled with the symbols shown in the legends, by means of the machine.

Ottawa, Canada.

ART. XIX.—*Iodobromite in Arizona*; by WILLIAM P. BLAKE.

THE rare compound of silver, iodine, bromine and chlorine, iodobromite, occurs in thin seams and crusts in a vein of quartz and calcite near Globe, Pinal County, Arizona. The crystallization is obscure. It is soft like talc; luster vitreous; color light lemon-yellow to sulphur- and canary-yellow. Not being able to secure enough for a satisfactory quantitative analysis, the results of the determinative tests are added. The reactions before the blowpipe are remarkably beautiful and interesting. Heated in a closed tube with bisulphate of potash, the mineral quickly changes color to a dark salmon, or orange-red, heavy brownish-red fumes of bromine are given off and bromine condenses in the higher portion of the tube; violet vapor of iodine then appears and crystals of iodine form below the condensed bromine. The fused assay, floating in the flux, is brilliant cherry red, at first very dark red, but on cooling gradually loses this color, passing through various shades of red until the normal yellow color is restored. The fused mass then being removed from the tube and reheated until the bromine and iodine are expelled, and treated with carbonate of soda on charcoal, a button of metallic silver is obtained. The fused carbonate of soda dissolved from the coal gives the reaction for chlorine with silver nitrate. In the final reduction of the assay to the metal a slight yellow areola like that from lead was observed and referred to probable slight impurity.

Arizona School of Mines, Tucson, Arizona.

ART. XX.—*Autophytography: A Process of Plant Fossilization*; by CHARLES HENRY WHITE.

THE evidence for the existence of plant life on the earth in past geological ages is both direct and indirect. We may include in the class of direct evidence all the records of vegetable life in which the form or structure of the plant is in any degree preserved, and in the class of indirect evidence, such as offer no clew to plant form, but merely indicate in a secondary way, the existence of vegetable life. In this latter class are coal and certain deposits of calcareous and siliceous sinters and bog-iron-ore. The plant records to which attention is especially directed in this paper may be placed in the category of direct evidence, since the trace or outline of the plant is distinctly preserved; but the process by which the outline is recorded in the rocks is wholly different from those processes to which the formation of plant records is usually attributed.

The ways usually described by which the plant form is recorded in the rocks may be included in the following three classes. The first class includes those in which the original substance, or tissue, of the plant is, in part at least, preserved. Such remains are often found within, or in close association with, deposits of shale, peat, coal, diatomaceous earth, and the like. The second class of records by which the form is preserved is that in which the plant tissues have been removed by decay or otherwise, leaving only the impress or mould as the record in the rocks. The third class is that in which the mould has been filled by a cast, either after the complete removal of the plant, or by a gradual so-called molecular replacement.

By the process of plant fossilization here described, the plant undergoing decomposition reproduces itself in outline on the rock surface upon which it rests, or upon the matrix within which it is enclosed, either by the precipitation of colored mineral matter, or by the alteration or removal of the coloring matter already in the rock. In the first of these processes the rock surface receives a deposit of colored mineral matter, a positive picture,—to borrow the language of the photographer,—is made (see figures 1 and 2); and in the second, the uniform coloring matter already in the rock is abstracted where the plant, during growth or decay, has been in contact with it, giving a plant picture in lighter color, a negative (figures 3 and 4). For such plant pictures, or plant writings, in which the traces or outlines of plants are distinguishable by their color, and in which the variation of color from the matrix is due to chemical change brought about by the plant reproduced,

the name autophytograph (*αὐτός* = self, *φυτόν* = plant, *γραφω* = write) is proposed.

Figures 1 and 2 represent specimens of the positive autophytograph that were collected by Dr. John W. White in December, 1897, from a bar of gravel on Cub Creek in the town of

1



2



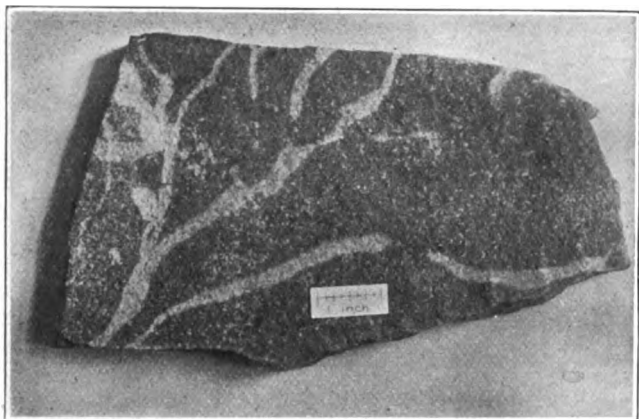
Wilkesboro, North Carolina, and were presented to the writer in January, 1898. These specimens* are water-worn pebbles of white quartzite that have been slightly stained brownish yellow by hydrated iron oxide, and that have, in recent time,

* All the specimens reproduced here are in the Harvard University Museum. Figures 1 and 2 are from two specimens No. 2559, figures 3 and 4 are Nos. 2667 and 2343, of the Geological Laboratory collection; and figure 5 is from No. 37 of the Students Palaeontological collection.

received a black deposit on their polished and stained surfaces, reproducing so perfectly the stem and leaves of a small herb that the species is readily identified. These autophytographs were determined by Mr. M. L. Fernald at the Gray Herbarium, Harvard University, through the kind intervention of Mr. Walter Deane, of Cambridge, Massachusetts, as having been produced by *Micranthemum orbiculatum* Michx., a small creeper that flourishes in low, muddy ground, from Florida to North Carolina.

The composition of the pigment of these autophytographs is difficult to determine, owing to the small quantity of material available. It is, however, a black adherent deposit, insoluble

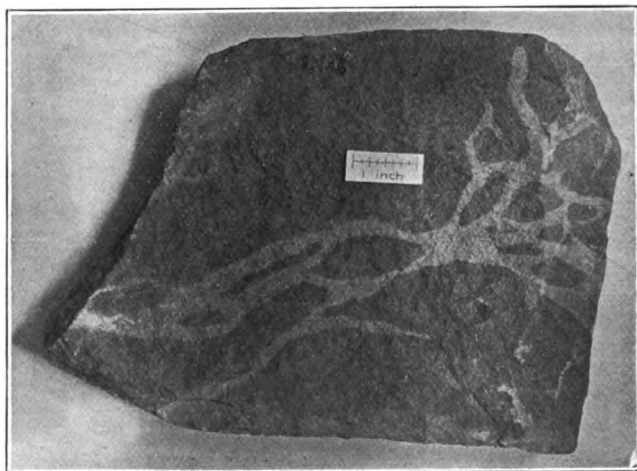
3



in water, but slowly attacked by the mineral acids, yielding solutions which show the presence of iron. No change of color is produced by the flame of the blow-pipe, but the pigment becomes strongly magnetic on heating. There is no doubt, therefore, that the colored deposit contains iron, and it is most probably an oxide. Two possible conditions under which it is believed such a deposit could form are suggested. First, the plants of this genus may yield on decomposition a precipitant of iron, peculiar to the genus, which extracts iron from the surrounding solutions and deposits it in a manner analogous to one of the artificial ink-making processes, and on exposure to the air the precipitate is changed to an oxide. The other suggestion is, that the conditions of decay are such that ammonia is liberated in the presence of iron in solution, precipitating the iron on the rock upon which the plant rests

during decay. For the precipitate to remain permanent, ammonia must be produced gradually and in sufficient quantity to neutralize the acid in the iron-bearing solution until the acid ceases to flow to the point of deposition. That vegetable matter undergoing decay will under certain and usual conditions produce acids which take iron in solution, and will under other conditions yield ammonia, is well known and need not be discussed here; but the nicety of adjustment of these conditions called for above would necessarily be rare, and,—if this be the correct theory,—would account for the scarcity of autophytographs of this description.

4

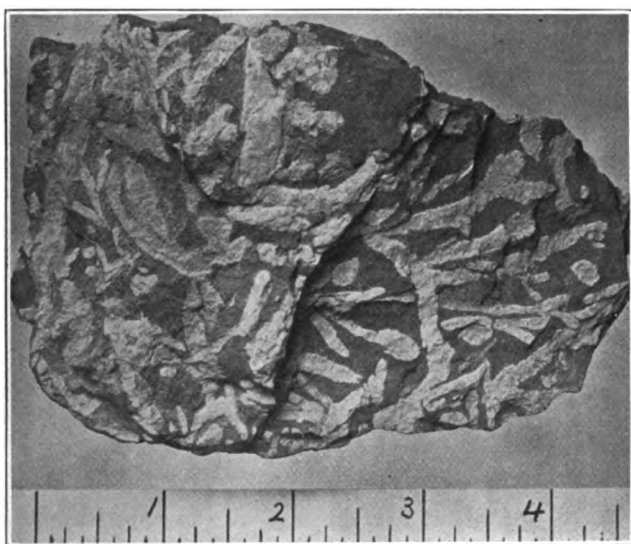


In figures 3, 4 and 5 are reproduced autophytographs of the negative type. The specimens represented by figures 3 and 4 are autophytographs of recent formation that were collected by Professor J. B. Woodworth of Harvard University, and it is through his kindness that they are here reproduced. The specimen represented by figure 3 is a block of sandstone, taken from the Saratogan, or upper Cambrian, formation near Biddle's Crossing, about a mile and three-quarters north of Sciota, Moore's quadrangle, Clinton County, New York, on which rootlets have in recent time brought about solution of the iron-pigment which stained the sandstone a yellow-brown, giving an autophytograph of lighter color on a dark background. Figure 4 represents a specimen taken from the ploughed surface of a lateral moraine at the west base of Bald Hill near Caroline Depot, Tompkins County, New York. This specimen

differs from the last only in having a darker iron-pigment in the rock, and in the form of the root reproduced, but in neither case is the portion of the plant reproduced sufficiently characteristic to identify the species.

These autophytographs belong in no sense to a past geological age. They were formed on or near the present land surface and show little evidence of having suffered disintegration and erosion. Granting that in transportation and deposition the probabilities are decidedly in favor of the destruction of these plant records, yet there are conditions of deposition and

5

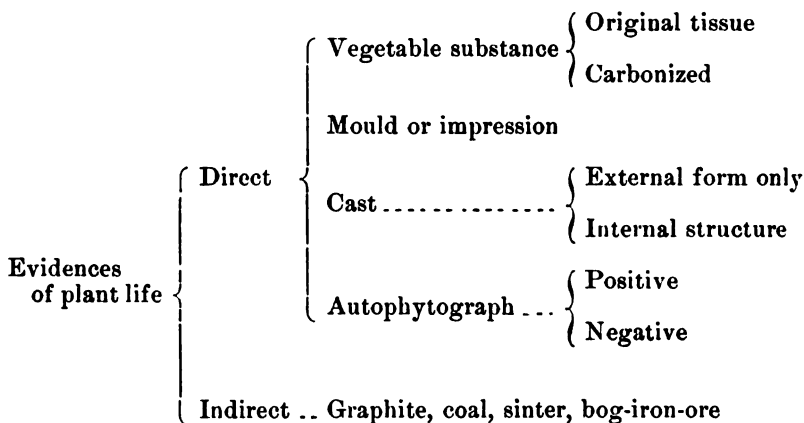


burial, not at all rare in nature, that would very effectively preserve such records to future geological time. While the specimens so far considered belong to the present and have no value as records for the historical geologist or palaeontologist, they well illustrate the process of autophytography and, as just pointed out, lead us to expect fossils of this character in the plant-bearing horizons of past geological time.

At the suggestion of Professor R. T. Jackson, the collection of fossil plants in the Harvard Botanical Museum was inspected, and it was found that fossil plants from many horizons partake of the quality of the autophytograph of both the positive and the negative type. Plant impressions in the slates at Solenhofen, Bavaria, marked out by oxide of iron have been observed

by Seward,* and similar impressions in the Buntersandstein of the Vosges were found by Schimper and Mougeot† to have either received a deposit of hydrated ferric oxide or to have had the red color of the rock removed from about the plant impression, the intensification or the removal of the coloring depending on the locality and the nature of the rock. In the Harvard collection are representatives of both these types from the Vosges and also from the Solenhofen deposits; as well as from many other localities. There are also examples in which the plant has left no impression or mould on the rock, but, at the same time, has been perfectly fossilized by negative autophytography. A fair representative of this class from the Lias of Germany is shown in figure 5. It is a specimen of *Fucoides bollensis*, collected at Boll, Würtemberg.

The various classes of evidence for the existence of plant life may be summarized as follows :



Harvard University, Cambridge, Mass.

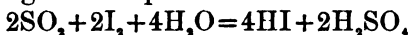
* A. C. Seward, *Fossil Plants*, vol. i, p. 63.

† Schimper et Mougeot, *Monographie des plantes fossiles du grès bigarré de la Chaîne des Vosges*, p. 10.

ART. XXI.—*The Oxidation of Sulphites by Iodine in Alkaline Solution*; by R. HARMAN ASHLEY.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxiv.]

ACCORDING to Bunsen, Dupasquer's method of oxidizing sulphurous acid by iodine in an acid solution, proceeds to completion according to the equation



only when the concentration of the sulphur dioxide does not exceed 0.5 per cent of the solution. When, on the other hand, the proportion of sulphur dioxide exceeds this value, there is a secondary reaction, which according to Volhard, involves the reduction of the sulphur dioxide by the hydriodic acid produced. This difficulty may be obviated, however, as has been shown by Volhard,* if the solution of the sulphurous acid or a sulphite is run with stirring into a solution of iodine in potassium iodide, acidified with hydrochloric acid, to the bleaching of color, using starch as an indicator,—a procedure which is obviously less convenient than direct titration by a standard solution of iodine.

It has been recently further proposed by E. Rupp† to accomplish the oxidation in an alkaline solution, by treating the solution of sulphur dioxide or a sulphite, with an excess of standard iodine in presence of acid sodium carbonate, 1 gr., during an interval of fifteen minutes, and determining the excess of iodine with sodium thiosulphate. Rupp's analytical examples, three in number, involving amounts of sulphur dioxide approximating 0.0343 gr., show small errors of excess, and from them the conclusion is drawn that sulphites like arsenites, may be estimated in a solution made alkaline with sodium bicarbonate, by the process indicated.

This very unusual use of sodium thiosulphate for the determination of free iodine in the presence of an alkali bicarbonate, suggests the question as to whether the sulphite was in reality completely oxidized by the treatment, or whether the apparently good results were in fact due to a chance balancing of errors of incomplete oxidization of the sulphite, on the one hand, and on the other hand, of the excessive use of iodine in the action of the thiosulphate in an alkaline solution, it being generally supposed that in alkaline solutions not only is the expected tetrathionate formed, but that some of the thiosulphate is oxidized to the extent of forming sulphate rather than tetrathionate exclusively.

In the following table of experiments are data of experiments upon the action of iodine and sodium thiosulphate in

*Ann. Chem., ccxlii, 93.

†Ber. Dtsch. Chem. Ges., xxxv, 3694.

alkaline solution. The sodium thiosulphate, approximately $\frac{N}{10}$, was standardized against approximately $\frac{N}{10}$ iodine solution in a neutral solution. Varying amounts of a saturated solution of acid sodium carbonate were used to render the solution alkaline in the experiments recorded.

TABLE I.
Iodine solution = 0·01286 gr. per cm^3 .
Sodium thiosulphate solution = 0·01516 gr. per cm^3 .

No.	$\text{Na}_2\text{S}_2\text{O}_3$, nearly $\frac{N}{10}$		Iodine nearly $\frac{N}{10}$		Error in terms of I.	NaHCO_3	Treatment.
	cm^3	I value, gr.	cm^3	gr.	gr.	cm^3	
1.	11·94	0·1451	15·00	0·1854	+0·0403	20	} $\text{Na}_2\text{S}_2\text{O}_3$ into Iodine.
2.	11·69	0·1421	15·00	"	+0·0433	20	
3.	11·18	0·1359	15·00	"	+0·0495	40	
4.	11·25	0·1367	15·00	"	+0·0487	40	
5.	9·18	0·1116	11·00	0·1360	+0·0244	1 gr.	
6.	9·11	0·1107	11·00	"	+0·0253	1 gr.	} Iodine into $\text{Na}_2\text{S}_2\text{O}_3$.
7.	15·00	0·1823	15·98	0·1975	+0·0152	20	
8.	15·00	"	16·31	0·2016	+0·0193	20	
9.	15·00	"	16·62	0·2054	+0·0231	40	
10.	15·00	"	16·05	0·2058	+0·0235	40	

It is plainly evident from the table that more iodine is used up in the presence of an alkali bicarbonate, whether the iodine is run into the thiosulphate or the thiosulphate into the iodine, than accords with the theory of the reaction.

Experiments were now undertaken for the purpose of contrasting the results obtained by Rupp's procedure with results found by oxidizing the sulphite with iodine in an alkaline solution and determining the excess of iodine by standard arsenite, which, as is well known, acts with regularity upon iodine in the presence of an acid sodium carbonate. The volumes of the solutions at the time of oxidation varied from 25cm^3 to 50cm^3 . The results are given in the following table:

TABLE II.
RUPP'S PROCEDURE.

Iodine value of SO_2 taken.	Iodine taken.	Iodine value of $\text{Na}_2\text{S}_2\text{O}_3$ taken.	NaHCO_3 taken.	Error in terms of Iodine.	Error in terms of SO_2 .
gr.	gr.	gr.	gr.	gr.	gr.
0·0977	0·2474	0·1492	1·	+0·0005	+0·0001
0·0977	0·2474	0·1454	1·	+0·0043	+0·0011
0·1440	0·2969	0·1528	1·	+0·0001	+0·0000
0·1440	0·2969	0·1518	1·	+0·0011	+0·0003
0·2759	0·4316	0·1582	1·	−0·0025	−0·0006
0·2759	0·4316	0·1628	1·	−0·0071	−0·0018

EXCESS OF IODINE DETERMINED BY STANDARD ARSENITE.

Iodine value of SO ₂ taken.	Iodine taken.	Iodine value of arsenite taken.	NaHCO ₃ taken.	Error in terms of Iodine.	Error in terms of SO ₂ .
gr.	gr.	gr.	gr.	gr.	gr.
0.0977	0.2495	0.1543	1.	—0.0025	—0.0006
0.0977	0.2495	0.1540	1.	—0.0022	—0.0006
0.1440	0.2984	0.1586	1.	—0.0042	—0.0010
0.1440	0.3017	0.1607	1.	—0.0030	—0.0008
0.2759	0.4354	0.1710	1.	—0.0115	—0.0029
0.2759	0.4354	0.1742	1.	—0.0147	—0.0037

From a comparison of the results in the second section of the table with those in the first section, it appears that under the conditions advocated by Rupp, the sulphite is not completely oxidized by the iodine. It seems that enough of the secondary action, by which the thiosulphate is oxidized beyond the condition of tetrathionate, takes place to counterbalance the error of incomplete oxidation when moderate amounts of sulphurous acid are handled, and more than enough for the smallest amounts, the secondary error predominating in such cases.

The results of experiments in which acid potassium carbonate was substituted for the acid sodium carbonate gave similar results.

So it appears that when Rupp's process gives results approximating the truth, it is due to the happy balancing of opposed errors. It seems quite possible that the same balancing of errors likewise occurs in the process for the determination of phosphorous acid described by Rupp and Fink.*

In conclusion, I would like to thank Prof. F. A. Gooch for many kind suggestions.

* Ber. Dtsch. Chem. Ges., xxxv., 3691, 1902.

ART. XXII.—*The Billings Meteorite: A new Iron Meteorite from Southern Missouri*; by HENRY A. WARD.

A NEW siderite is now added to the six meteorites (four siderites and two aerolites) already found in the state of Missouri. The mass was found on the farm of Geo. Wolf about four miles east of Billings, Christian County, Southwestern Missouri, in breaking new ground in September, 1903. It was taken by Mr. Wolf—who considered it an iron ore,—to a street fair held in Billings in the same month, where it took the first prize as Iron Ore. The attention of J. P. Thomas was called to it, and



Billings Siderite, $\frac{1}{4}$ size.

he had a horse-shoe nail made from a piece of it and a hole drilled through the edge of the mass to test its quality. Mr. Thomas shipped it with a large number of specimens of iron ore to Kansas City, Mo., where it was bought by Mr. R. E. Bruner, a gentleman who possesses a fine collection of minerals. It remained in Mr. Bruner's hands until I obtained it from him last November.

In general shape the Billings siderite rudely resembles an axe or hatchet, as may be seen from the cut here given. Its extreme length is $15\frac{1}{4}$ inches; its greatest breadth $8\frac{1}{4}$ inches. The thickness at the larger end is 5 inches, while from the middle the mass flattens out into a blade or wedge, which is about 3 inches thick on a medium line, and slopes off to a blunt rounded edge at the sides and end. This iron has evidently

lain in the ground for a long time since its fall. Its outer surface is rusty and covered with flaking scales of oxide. There consequently remains upon its surface no sure trace of "pitting" or other aerial action incident upon its flight and fall through our atmosphere. A single circular concave depression, four inches across by one inch in greatest depth, on one side of the mass may be the remains of an original pitting on the original surface. The weight of the mass before cutting was 54 lbs. Several slices have been made under my direction which show fine Widmannstätten figures of the octahedral system. Of the structure and composition of the iron alloys inducing these figures I am indebted to Prof. Oliver C. Farrington of the Field Columbian Museum of Chicago for the remarks which follow.

The Billings iron is a coarse octahedrite (Og), with lamellæ averaging from 1–2^{mm} in width. In length many of the lam-



Section of Billings Siderite, $\frac{1}{2}$ size.

ellæ extend 2^{cm} without interruption. They are as a rule comparatively straight in outline, but again become irregular and swollen and at times merge into areas where their outlines are so nearly rounded as to give a coarse-granular appearance. The substance of the lamellæ is sometimes interrupted and sometimes shows subdivision longitudinally into narrower bands by more or less continuous films of tænite. The kamacite is coarsely granular in character, and shows oriented sheen. The tænite appears as a dark, narrow line, in general bordering the kamacite, but also not infrequently crossing and anastomosing. In portions of the meteorite, where some decomposition has taken place, the tænite separates out as thin, flexible, magnetic plates of a tin-white color.

The meshes (Felder) of the section occupy but small space relatively to the bands (Balken) but are well defined where they occur. They range in size from about 25^{sq mm} down, and in outline from triangular to trapezoidal. They are filled with a substance darker in color than the kamacite, and are

traversed by irregular numbers of delicate plates seen only under a lens, which run now in one and now in several directions. As a rule these plates start in great numbers from the borders of the mesh and thin out toward the center, but in some of the meshes they extend uniformly across. Several nodules of troilite appear in the section examined and as usual occur near its boundary. One of these nodules is irregularly oval in shape and has a diameter of about one centimeter. The others are smaller, and range in outline from nearly circular to considerably elongated. None of them has a border of swathing kamacite. A line of irregular parting extends across the section, following roughly the lamellar planes, except at about the middle of the section, where it runs nearly straight for a distance of about 2^{cm} quite irrespective of the lamellar structure. The parting at this point has a width of about one millimeter, and is filled with a substance of the section. This substance shows a foliated structure parallel with the length of the tænite, others kamacite. The structure is evidently secondary in character and appears to be a filling subsequent to the individualization of the main mass.

The chemical analysis of the iron has been made by Mr. H. W. Nichols, the chemist of the Field Columbian Museum, and is as given below:

Analysis of Billings Iron

Fe.....	91.99
Ni.....	7.38
Co.....	0.42
Cu.....	0.01
Si.....	0.08
P.....	0.15
S.....	0.06

100.09

The larger part of this Billings siderite has taken its place in the Ward-Coonley Collection of Meteorites.

Chicago, Illinois.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Atomic Weight of Iodine.*—A series of careful determinations of this constant has been carried out by G. P. BAXTER of Harvard University. The ratios of silver to silver iodide, silver to iodine, and silver iodide to silver chloride were found in making these determinations, and the average of very closely agreeing results by the three methods were 126.973, 126.977 and 126.975, where oxygen as 16 is taken as the basis. Several other investigators—Scott, Ladenburg, and Köthner and Aener—have recently obtained results upon the same atomic weight which agree almost exactly with those of Baxter; hence it appears certain that the atomic weight 126.85 for iodine, which has been accepted for many years on the authority of Stas and of Marignac, is somewhat lower than the truth. In spite of his wonderful skill, it seems that Stas was not quite infallible in his atomic weight determinations. The international committee on atomic weights, in the table for 1905, has adopted the value 126.97 for the atomic weight of iodine, when oxygen is 16, and the value 126.01, when hydrogen is taken as unity. Both of these numbers, it may be noticed, are curiously close to being confirmations of Prout's old hypothesis, which requires, practically, that the atomic weights should be whole numbers.—*Zeitschr. anorgan. Chem.*, xliii, 14.

H. L. W.

2. *Double Silicides of Aluminium.*—MANCHOT and KIESER have obtained the crystalline compounds Cr_2AlSi and Cr_3AlSi by the fusion of chromium compounds with an excess of aluminium in the presence of potassium silicofluoride, and treatment of the resulting metallic mass with an acid in order to dissolve the aluminium. The compound, Cr_2AlSi , forms beautiful slender crystals of hexagonal habit, which are opaque, with a strong metallic luster and white color. The compound is very inactive with most chemical agents. It is insoluble in acids, except hydrofluoric acid; it remains bright when heated in a stream of oxygen, and is not attacked by fusion with potassium bisulphate; but it readily decomposes by fusing with alkalis. The other compound was obtained in a similar way in the presence of a larger amount of silicon. It forms smaller crystals, is somewhat harder, but otherwise it is like the first compound in its properties. These compounds are the first double silicides to be described.—*Ann. der Chem.*, cccxxvii, 353.

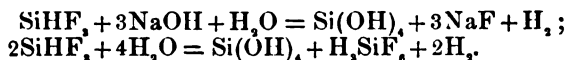
H. L. W.

3. *Europium.*—This element, occurring in very small quantities among the rare earths and coming between samarium and gadolinium, was described by Demarcay several years ago. URBAIN and LACOMBE have recently confirmed the existence of the earth. They used 610 g. of oxides representing the whole of the europium group of earths from about 500 kilos of monazite

sand, and by a long series of fractionations involving some 3000 crystallizations, they obtained several fractions of constant properties and atomic weight, apparently consisting of pure europium. The amounts obtained indicated that the monazite sand contained about two hundred-thousandths of europium oxide. The sulphate has a scarcely visible rose tint, while the oxide prepared at a low temperature is practically white, although when intensely ignited it is distinctly rose-colored. Closely agreeing atomic weight determinations made with several different fractions gave 151.79 as the result, which the authors believe to be true within .06. Demarçay had given the atomic weight as about 151.—*Comptes Rendus*, cxxxviii, 628. H. L. W.

4. *The Use of Calcium Carbide as an Explosive in Mining.*—GUÉDRAS has described a method of utilizing the explosive force of acetylene for mining purposes. A sheet-iron cylinder is used as a cartridge. At its bottom are placed about 50 g. of granulated calcium carbide, and above this in a separate compartment is a sufficient amount of water to react with the carbide. There is also an air-chamber containing an electric fuse. The cartridge is placed in the hole to be exploded, the latter is closed with a wooden plug, and an iron rod attached to cartridge for the purpose of piercing the water compartment is struck, thus liberating the acetylene. After this has been disengaged for about five minutes, the mixture of air and acetylene is exploded. The explosion causes the rocks to fly about much less than would be expected, but they are thoroughly broken up.—*Comptes Rendus*, cxxxix, 1225. H. L. W.

5. *Silicon-fluoroform.*—The silicon compound, SiHCl_3 , silicon-chloroform, is well known, and recently RUFF and ALBERT, by allowing the compound just mentioned to act upon tin tetrafluoride or titanium tetrafluoride, have succeeded in obtaining the corresponding fluorine compound. Silicon-fluoroform is a combustible gas which liquefies at atmospheric pressure at about -90° and solidifies at about -110° . It is decomposed by water and alkaline solutions without change of volume, for the hydrogen produced by the decomposition is equal in volume to the original gas, as is evident from the following equations :



The preparation of the compound under consideration completes the series SiHF_3 , SiHCl_3 , SiHBr_3 , and SiHI_3 of analogous halogen compounds.—*Berichte*, xxxviii, 53. H. L. W.

6. *Double Cyanides of Copper.*—A considerable number of these double salts has been prepared and studied by GROSSMANN and VON DER FORST. They are all cuprous salts, and contain lithium, sodium, potassium, rubidium, caesium, as well as ammonium, calcium, strontium, and barium. Five different types of double salts were noticed ; for instance, omitting water of crystallization, I. $\text{KCu}_2(\text{CN})_6$, II. $\text{Rb}_2\text{Cu}_2(\text{CN})_6$, III. $\text{KCu}(\text{CN})_3$, IV.

$\text{Na}_2\text{Cu}(\text{CN})_4$, V. $\text{K}_2\text{Cu}(\text{CN})_4$. The salts of type III were obtained in the largest number. It may be mentioned that all of these types occur among the known cuprous double chlorides.—*Zeitschr. anorg. Chem.*, xliii, 94.

H. L. W.

7. *An Occurrence of Radium and Radio-active Earths.*—F. GIESEL has found that mud from Fango and soil from Capri possess an activity of about one one-thousandth of that of pitchblende, and that it is possible to extract radio-active products from them by chemical methods. For instance, from 40 kg. of the Capri soil about half a gram of barium bromide was extracted, which showed distinct spontaneous phosphorescence upon dehydration. In neither of the materials could uranium be detected.—*Berichte*, xxxviii, 132.

H. L. W.

8. *N-Rays.*—E. GEHECKE describes at length certain hallucinations which might arise in the investigation of the so-called N-rays. He finds that any object, the forefinger for instance, moved to and fro behind a phosphorescent screen produced a change in the light of the screen. The effect is not produced if an independent observer moves the object; and it is therefore a psychological one. The author believes that the phenomenon is analogous to many which arise at the extreme limit of vision. For instance one often believes that he sees a faint image while developing a photographic plate when no such image really exists. The author does not attempt to explain the photographs obtained by Blondlot and he remarks that in whatever way the phenomena of N-rays may be explained, Blondlot has rendered a service in calling attention to interesting phenomena.—*Physikalische Zeitschrift*, No. 1, Jan. 1, 1905, p. 7-8.

J. T.

9. *Photography of N-rays.*—G. WEISS and L. BULL have failed to obtain such registration, and remark that Blondlot now concludes that the rays increase or affect visibility and not luminosity.—*Comptes Rendus*, cxxxix, Dec. 12, 1904, pp. 1028-1029.

J. T.

10. *Spectra of Electric Discharges in Cooled Geissler Tubes.*—E. GOLDSTEIN describes the distribution of light and the spectra produced by suddenly immersing Geissler tubes in liquid air. The method appears to be of use in obtaining the spectra of metals in great intensity and with sharp lines. It also reveals a difference in the cathode light, according to the kind and nature of the cathode.—*Physikalische Zeitschrift*, No. 1, Jan. 1, 1905, pp. 14-17.

J. T.

11. *The Dependence of the Ultra-Red Spectrum of Carbonic Acid upon Pressure.*—CLEMENS SCHAEFER concludes from his investigation on this subject that Arrhenius' theory in regard to the ice age is erroneous. The latter concluded from his figures that a diminution of the amount of carbonic acid in the earth's atmosphere would lead to a fall of temperature of the earth, and in consequence of diminished absorption there would be an increased radiation of heat from the earth into space. Thus an ice age might have been caused. Schaefer shows that the con-

clusion that variation in thickness of layer and variation in pressure have similar effect upon absorption is not justified. Changes of volume amount of CO_2 have no influence on the earth's temperature so long as the diminution of carbonic acid remains under 80 per cent of the former quantity.—*Ann. der Phys.*, No. 1, 1905, pp. 98–105. J. T.

12. *Electromagnetic Waves in the Visible Spectrum*.—Many attempts have been made to identify these waves with light waves. FERDINAND BRAUN forms suitable resonators or “Gitters” by deflagrating very fine wires stretched on glass plates; and then observing changes of polarization by means of suitable optical devices directed upon the particles of finely divided metal. According to the electromagnetic theory these “Gitters” should allow little light through if the arrangements of the particles are parallel to the electric vector, and much if they are perpendicular to it. The author believes that his photographs show a complete analogy between Hertz waves and optical waves. He shows also that the method he employed is of importance in mineralogical work.—*Ann. der Phys.*, No. 1, 1905, pp. 1–19. J. T.

13. *Damping Galvanometer Deflections*.—W. EINTHOVEN continuing his investigations on his new galvanometer, which consists of a silvered quartz fiber stretched in a strong magnetic field, finds that a condenser attached to the terminals of the fiber is of great use in bringing the oscillations to rest even when they are extremely rapid. It is believed that the method will be of great advantage in acoustical investigations and also in physiological work.—*Ann. der Phys.*, No. 1, 1905, pp. 20–31. J. T.

14. *Possible variation in Solar Radiation*.—The report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1904 (noticed on p. 260), contains in the statement of the work accomplished at the Astrophysical Observatory, under the charge of C. G. Abbot, a further discussion of the possible variability of the sun first rated in the report of the year preceding. We quote the following paragraphs:

“Notable progress has been made with the researches you have initiated on the amount of solar radiation and its absorption in the solar envelope and in our atmosphere. Within the last seventeen months three independent kinds of evidence have been collected here, pointing toward the conclusion that the radiation supplied by the sun may perhaps fluctuate within intervals of a few months through ranges of nearly or quite 10 per cent, and that these fluctuations of solar radiation may cause changes of temperature of several degrees centigrade nearly simultaneously over the great continental areas of the world. Further evidence must, however, be awaited to verify this important conclusion.

The three kinds of evidence referred to are as follows: First, on all favorable days the ‘solar constant’ of radiation outside our atmosphere has been determined here, and changes of about 10 per cent in the values obtained have been found which cannot be attributed to known causes. Second, the solar image formed by

the horizontal telescope has been examined with the spectrometer to determine the absorption of radiation within the solar envelope itself. If we grant for argument's sake that the rate of solar radiation outside our atmosphere fluctuates rapidly from time to time, then as you have observed, the cause of this fluctuation cannot reasonably be a variability of the temperature of so immense a body as the sun itself, but must rather be in a change in the absorption of a more or less opaque envelope surrounding the sun. Accordingly the two researches I have mentioned are intimately associated, for if we find a considerable increase in the rate of solar radiation outside our atmosphere we ought to find a corresponding decrease in the absorbing power of the solar envelope.

Such is in fact one of the most notable results of the year's work. In August, September, and October, 1903, the observations of the 'solar constant' of radiation indicated that the rate of radiation was about 10 per cent below that observed in February, 1904. On the other hand, measurements of the absorption of the solar envelope indicated considerably less absorption in February, 1904, than in September, 1903.

The third kind of evidence of change in solar radiation is based on a study of the temperature of the North Temperate Zone, as indicated by the *Internationale Dekadenberichte* published by the Kaiserliche Marine Deutsche Seewarte, and received at the Observatory through the kindness of the Librarian of the United States Weather Bureau. This publication gives the mean temperature at 8 A. M. for each ten days at each one of about one hundred stations distributed over the principal land areas of the North Temperate Zone, and for about ninety of these stations there is also given the normal temperatures for the same ten-day periods, representing the mean of many years. From these data there have been computed here the temperature departures from the normal since January 1, 1903, and these are compared graphically in the accompanying chart, Plate VII,* with the measures of the solar constant made in 1903. It will be seen that shortly after the observed fall of solar radiation in March, 1903, a general fall of temperature occurred, which would be a natural result of such a change. It has been shown here, in accordance with the known laws of radiation, that 10 per cent fall in the solar radiation could not produce more than $7^{\circ}5$ C. fall in terrestrial temperatures, and that several causes, notably the presence of the oceans, would prevent so great a change of temperature as this resulting from a temporary diminution of solar radiation of only a few months' duration. The observed fall of about $2^{\circ}5$ C. in the mean temperature of the land areas of the North Temperate Zone during April, 1903, seems to be therefore in good accord with the observations of solar radiation.

Owing to the uncommon cloudiness of the first six months of

* Shown also in your article on "A Possible Variation of the Solar Radiation," *Astrophysical Journal*, June, 1904.

1904 few measures of the 'solar constant' worthy to be compared with the series of 1903 have been obtained, but taking the best of the measures it appears that high values of solar radiation in February, 1904, and lower ones in the subsequent months are indicated, as shown in Table II, given below. This appears to be in general accord with the mean temperature observed over the North Temperate Zone, except that it seems probable that the solar radiation was high in January as well as February, but the lack of good observing weather prevented our recognition of it."

The importance of this subject is remarked upon in its bearing upon forecasts of temperature, in case further research serves to confirm the indications now obtained as to a general parallelism between measures of solar radiation and terrestrial temperature. For this work, however, a better station for observation than Washington is needed.

15. *Terrestrial Magnetism. Results of Magnetic Observations made by the Coast and Geodetic Survey between July 1, 1903, and June 30, 1904*; by L. A. BAUER. Appendix No. 3, Report for 1904. Washington, 1904.—This report* contains the usual detailed statement of magnetic observations made in the United States and outlying territories during the year ending June 30, 1904; an interesting feature is the introduction of observations made at sea by the Survey vessels, this is a new departure begun in February, 1903. In the introductory summary of results reached some interesting notes are made, particularly in regard to the changes of magnetic declination in Louisiana. We quote some paragraphs:

"The results of this detailed work in Louisiana have been extremely interesting. First, it has been clearly demonstrated that there was a reversal in the expected course of the secular variation which took place about 1898. Past observations made in the vicinity of New Orleans show that the magnetic declination, which is east, reached a maximum amount of about $8\frac{1}{2}^{\circ}$ near the year 1830. It then began to diminish, and, in accordance with the laws of the secular variation pertaining north and east of the agonic line, i. e., in the Atlantic States, where west declination is known to be increasing at present on the average about three minutes per year, a turning point was under ordinary conditions not to be expected before some time about the middle of the present century. Instead, however, it was reached about 1898, so that east declination reached a minimum value of $5\frac{1}{4}^{\circ}$ in about seven decades after a maximum value—the shortest interval between a maximum and a minimum value thus far revealed anywhere on the earth. East declination is now increasing in Louisiana at the rate of about one and one-half to two minutes per annum. The total change between maximum and minimum at New Orleans, as above stated, was about $3\frac{1}{4}^{\circ}$.

The early reversal produced a larger annual change between the years 1860 and 1870—about six minutes—than has generally been experienced in the United States, although elsewhere, as, for

* See also p. 261.

example, England, such large annual changes and even greater ones occur. Values of the magnetic declination secured four to five decades ago, if referred to the present time with the aid of secular change values as were expected, in accordance with the experience in other parts of the United States, would be in error one-third to one-half degree.

Observations in other States near Louisiana show that this change in the course of the secular variation is manifesting itself in greater or less degree, according to locality, likewise in these States. How permanent the present change may be, i. e., whether it will continue for but a comparatively short period, so that before long another reversal may be expected, after which east declination will begin to diminish once more, can not be stated at present.

The magnetic survey of Louisiana has revealed other most interesting features, as shown by the lines of equal magnetic declination, dip, and horizontal intensity, drawn in conformity with the observations. There were noticed marked relations with well-known physiographic features. The curvatures and bendings of the lines of equal magnetic declination appear to conform with courses of principal streams and shore lines of certain bodies of water. Also a marked difference manifested itself in the general direction of these lines in the middle of the southern part of the State, just where there is a dividing line between the newer and older geological formations.

It is especially interesting that the irregularities in the distribution of the earth's magnetism, as exhibited by the three sets of lines, occur chiefly in the regions of the alluvial deposits brought down by the Mississippi River. Owing to these irregularities the compass needle is deflected from the direction it would ordinarily have assumed by amounts varying from about $0^{\circ}1$ to $0^{\circ}5$. They are not local disturbances of such amount which ordinary instruments would readily reveal, but they are of such a magnitude as only approved instruments and methods would indisputably expose. This point can not be emphasized too strongly for the sake of geologists who undertake to discover relations between magnetic disturbances and geological formations, employing crude instruments, and using imperfect methods.

Quite likely these irregularities are to be referred to small local deposits of iron ore brought down from the upper States by the Mississippi River."

16. *An Introduction to the Study of Spectrum Analysis*; by W. MARSHALL WATTS. Pp. vii, 325, 8vo. London and New York, 1904 (Longmans, Green & Co.).—The first impression from a hasty inspection of this work is the extraordinary variation in the character and value of the numerous illustrations contained in it. We recognize some cuts which are familiar in popular works on spectroscopy from as early a date as 1870, and which might have been omitted even then with profit to the reader. A number of those illustrating the very primitive treatment of the

optical theory of the spectroscope are subject to this criticism ; and fig. 15, intended to show the path of the light through a powerful prism spectroscope, could hardly be modified so as to give more hopelessly false ideas as to the optical principles involved. A critical reading shows an analogous lack of uniformity in the unexpected relative importance attaching to the different topics treated. Probably few spectroscopists would approve the ratio of eight pages devoted to absorption spectra to only two appropriated to the explanation and application of Doppler's principle. A single page is given to the subject of spectroscopic binaries, of which α Ceti and β Cygni (with relative magnitudes reversed) are cited as examples. It would be difficult to imagine errors which would be more confusing to a beginner. This is immediately followed by more than six pages on the spectra of comets. Another peculiarity is an utter lack of system in the orientation of cuts representing spectra. In many, the wave-lengths decrease from left to right, while in the others the reverse order is employed ; nor is it always easy to tell, either from the figure or from the text, which arrangement is selected.

On the other hand, there are features which will make the book a welcome addition to every scientific library. The copious references to sources and the extended tables of spectra at the end of the volume will certainly prove conveniences. Then, too, the chapter on the Michelson Echelon spectroscope is so satisfactory that one wonders why the important theory of the concave grating is wholly neglected. C. S. H.

17. *The Reflecting Telescope*. From Vol. XXXIV of Smithsonian Contributions to Knowledge.—This publication consists of two parts, the first of which is a reprint of the celebrated paper by Professor Henry Draper, On the Construction of a Silvered Glass Telescope, published in 1864 in Vol. XIV of the same series. This is so well known to all amateur and working opticians that a review of it here is quite unnecessary. The second part, of nearly the same length, bears the title, On the Modern Reflecting Telescope and the Making and Testing of Optical Mirrors, by George W. Ritchie of the Yerkes Observatory. This is a highly interesting description of the refined methods which have been gradually introduced during the forty years which have lapsed since the appearance of the earlier paper, illustrated especially by the experience of its author in constructing 24- and 60-inch parabolic mirrors in the optical shop of the Yerkes Observatory. The frontispiece is an enlargement of the admirable photograph of the central portion of the Great Nebula in Andromeda, taken by Mr. Ritchie with the 24-inch mirror. A comparison of the illustrations of the two papers—both of the highest excellence attainable at their respective periods—is most instructive. C. S. H.

18. *An Introduction to the Theory of Optics* ; by ARTHUR SCHUSTER. Pp. xv, 340. London, 1804 (Edward Arnold).—This is a notable addition to the literature on optics. The first

two hundred pages are occupied with a general description of the phenomena of optics with their mathematical theory. Chapters iv, v and vi, on interference of light, diffraction, and diffraction gratings, respectively, are especially good. The chapter on the theory of optical instruments, however, leaves much to be desired; the theory of the microscope is not touched upon, and a theory of the telescope, which leads to the conclusion that a magnification of eight to the inch of aperture of the objective quite exhausts its resolving power for an eye free from spherical aberration, is necessarily erroneous.

Part II, on modern theories of light, of dispersion and absorption, and of the relations of optical to electromagnetic phenomena, containing all that is very recent in optical science, is of greater value and interest. A careful reading of this portion is certain to be profitable to every student of physics. The treatment of Talbot's Bands (p. 329) may be cited as specially interesting and suggestive.

The illustrations of the work are not wholly satisfactory, with the exception of its two plates which are reproductions of direct photographs of interference phenomena. Unfortunately, the references in the text to these plates contain many errors which would prove very confusing to one not already familiar with the phenomena. We may add that the first figure on Plate I, showing the interference bands formed by a biprism, owes its irregularities to a defective prism, not, as is asserted in the text, to the periodic nature of light itself.

C. S. H.

19. *Das Elektrische Bogenlicht; seine Entwicklung und seine physikalischen Grundlagen*; von W. B. von Czubnowski. Erste Lieferung, pp. viii, 98. Leipzig, 1904 (S. Hirzel).—The first part of this work upon the electric arc light was issued some months since and is largely devoted to the physical side of the subject. The entire work is to be published in six similar parts, and from what we have before us may be expected to satisfy all demands as to fulness of description and illustration.

II. GEOLOGY AND MINERALOGY.

1. *A Treatise on Metamorphism*; by CHARLES RICHARD VAN HISE, U. S. Geological Survey, Monograph XLVII, 1286 pp., 13 pl., 32 figs.—Professor Van Hise's Treatise on Metamorphism will undoubtedly take rank as one of the most important single publications ever issued by the Geological Survey. The volume is the outcome of a life-long study in the province of metamorphic geology. Partial views have been published in his earlier papers, and the ground work of metamorphism has, of course, been gradually established through the labors of many leaders in geology during the past century. Nevertheless the subject is doubtless indebted to Van Hise more than to any other one individual for its reduction to an exact science. In the present treatise a highly successful attempt has been made to arrange the

phenomena of metamorphism in order and to show how they are throughout the expression of chemical and physical laws operating within the crust of the earth.

The earliest stage of science is largely descriptive, qualitative and speculative. The branch of metamorphic geology may now be said to have fully passed through such a preliminary stage and to have entered upon its final development. Although many able works have appeared in the past this treatise must be looked upon as the landmark of a new era, a starting point from which further studies will largely take their departure. Following these introductory statements the volume itself may be described.

In the introductory chapter it is shown that a great difficulty in studying metamorphism arises from the fact that many of the changes take place under conditions which cannot be directly observed, so that the forces and agents accomplishing certain results must be inferred from the nature of the results. This method is directly the opposite of that which has usually been applied to the elucidation of surface geology, and this fact gives the peculiar difficulty to the deeper problems of metamorphism and has retarded its development to a period later than that of any other branch of the science.

Under metamorphism is embraced not only the changes which take place in the deeper parts of the lithosphere but surface alterations as well, so that the treatise covers a large part of the ground of the older treatises on chemical and physical geology.

It appears that the processes of metamorphism, using the term in this inclusive manner, come under surprisingly few heads. The upper zone, characterized by hydration, oxidation, carbonation, resulting in expansion of volume and production of heat, tends to break down complex mineral molecules into a few of relatively simple composition and, following the analogy of the term of katabolism in biology, the zone is called the *zone of katamorphism* ("kata" meaning tearing down). This zone is divided into a *belt of weathering* extending to the level of ground water and below this a *belt of cementation*, within which is deposited much of the silica and other substances carried downward from the belt of weathering.

The zone of katamorphism corresponds roughly with the zone of fracture. Below this pressure due to gravity becomes the dominant factor in reactions. Complex compounds whose formation is attended by contraction of volume result from more simple ones. The reactions are characterized by a tendency to dehydration and decarbonation where water or carbonic acid is present. Again, following the analogy from biology, this zone, in which complex molecules are built up, is named the zone of anamorphism (from "ana" meaning a "building up"), and corresponds in general with the zone of flowage, the one term expressing the character of the chemical and mineralogical changes, the other the character of the mass deformations.

In both zones it is believed that the total reactions involve the

liberation of heat, in the outer zone from chemical reaction, in the inner from reduction of volume; and thus metamorphism conforms to the apparent law of the universe of dissipation of energy.

Chapter II treats in detail of the forces of metamorphism; chemical energy, gravity, heat, and light. Chapter III of the agents, which are gaseous and aqueous solutions and organisms.

Of great use to the working geologist and mineralogist is chapter V, which treats individually of the geological relationships, genesis and alterations of each of the rock-making minerals. The alterations are ordinarily such as take place in the zone of katamorphism, but the author points out that upon the altered materials being brought again into the zone of anamorphism the reactions are reversible and, provided that the results of decomposition are present in suitable proportions, the original mineral may be reproduced. Some of the more complicated reactions have been written out chemically for the first time, and, as pointed out by Van Hise, must be looked upon as first approximations and suggestive for further study.

The following three chapters, VI, VII, VIII, treat in detail of the belt of weathering, the belt of cementation and the zone of anamorphism. In regard to the belt of weathering besides a statement of the laws governing the changes a number of new features are developed, but special emphasis is placed on systematization under laws of physics and chemistry, of a vast number of facts already known.

In chapter VIII, among other matters are treated the meaning and method of rock flowage, the generalization being arrived at that rock flow is mainly accomplished through continuous solution and deposition, that is, by recrystallization of the rocks through the agency of the contained water, the rocks throughout, with the exception of an inappreciable amount which at the moment is in solution, being crystallized solids.

The student of metamorphic geology is expected as a matter of course to study carefully the entire monograph and a review should hardly be written for him, but rather for the general student of geology.

To such, perhaps, the most interesting chapter is the eleventh, upon *the relations of metamorphism to the distribution of the chemical elements*, and a more extensive review of this chapter will therefore be given.

Metamorphic processes operating upon the lithosphere have redistributed the elements of the original igneous rocks tending to segregate them into the several groups of sedimentary rocks, the hydrosphere and atmosphere, this redistribution concerning many large questions of geological theory. The author states,—“So far as practicable redistribution is dealt with in a quantitative way, . . . made more with a view of stating the various problems which in the future will undoubtedly be satisfactorily

treated quantitatively rather than with the belief that the calculations given even approach accuracy. Indeed this chapter is no more than an attempt to blaze a trail in the wilderness."

The author then considers the average composition of the lithosphere, the sedimentary rocks, the hydrosphere and atmosphere, using the work of F. W. Clarke, Dittmar and Farrington. The sedimentary rocks with certain portions of the hydrosphere and atmosphere, if recombined should give the average composition of the igneous rocks from which they were originally derived, and as a first approximation the shales are estimated at 0.65, the sandstones 0.30, and the limestones 0.05 of the sedimentary rocks; and the average thickness of the latter upon the surface of the continents which have always remained within the zone of katamorphism is estimated at two kilometers, this being less than has usually been estimated.

The results indicate that this relative proportion of the sediments must be in the neighborhood of the truth. In regard to the thickness of the sediments, however, Van Hise is inclined to think that even the moderate estimate of two kilometers may be too great. By assuming a smaller thickness, however, the character of the results would not be changed but only the absolute amounts of the surpluses and deficiencies. From these data some surprising results are obtained. To oxidize the ferrous iron of the igneous rocks to the ferric state in which it is usually found in the sediments would require 35 per cent of the oxygen now in the atmosphere. The further oxidation of the metals and the sulphur united as sulphides in the original rocks would require twice the oxygen now in the atmosphere. Further quantities have been consumed in the formation of nitrates. "In summary it appears that the chief certain source of oxygen for the atmosphere is the reduction of carbon dioxide by vegetation and the burial of a part of this vegetation in the earth. This source is vast in amount. On the other hand . . . the oxygen consumed during geological time . . . has been enormous. It probably vastly exceeds the amount which has been liberated to the atmosphere by the reduction of carbonic acid through plants."

"If this conclusion be correct, such wild guesses as those of Koene and Phipson, that the carbon dioxide of the original atmosphere greatly exceeded the oxygen and that the proportions of these elements have been reversed in consequence of the reduction of carbon dioxide by organic matter, are wholly unwarranted."

Under *sulphur*, it is shown that the proportion of sulphur in the secondary rocks and ocean is more than four times as great as in the original igneous rocks. It is thought highly probable that the discrepancy is largely explained by the actual escape of much sulphur as a gas during periods of volcanism, the igneous rocks containing only the residual sulphur which separated as a sulphide when the magma crystallized. The same explanation probably applies to a similar excess of carbon and chlorine.

It is found that silica shows an excess of 3.2 per cent in the secondary rocks and alumina a deficiency of 3.7 per cent. The author suspects that this discrepancy is largely due to errors in the determination of the silica and alumina in the analyses of shales.

Some of the general conclusions in regard to carbon are already somewhat familiar through the work of Chamberlin and others, the amount which is locked up in the sedimentary rocks being estimated at many hundred times that contained in both the atmosphere and hydrosphere.

"The chief processes which abstract carbon dioxide from the atmosphere are those of carbonation and the building up of carbonaceous deposits. All the replenishing processes, including the reversing processes of silication and the oxidation of buried carbon compounds, have been barely able to keep a minute portion of the carbon dioxide in the atmosphere. . . . It is probable however that the work of man, especially during the last half century, has returned a great volume of carbon dioxide to the atmosphere by the artificial oxidation of carbonaceous material, and thus has reversed the average of the processes of nature, which plainly appear to have caused depletion of the carbon dioxide in the atmosphere. In consequence, at the present time the amount of carbon dioxide in the atmosphere may be increasing rather than decreasing."

In treating of the alkalies it is shown that the amount of potassium in the sedimentary rocks and the ocean agrees fairly well with the proportions in the original igneous rocks. In the case of sodium, however, there is a remarkable deficiency in the sedimentary rocks, and even when the salt of the ocean is added the total sodium reaches a proportion not more than one-third of that in the original rocks.

"It is, therefore, plain that we must turn to some other direction to account for the great deficiency of sodium in the ordinary sedimentary rocks. The natural direction to which to turn is to the salt deposits of the world. . . .

"From the foregoing it appears highly probable that we must look to the salt deposits and to the alkaline deposits of arid regions to explain the great deficiency of sodium in the ordinary sediments rather than to the ocean. If this conclusion be correct, calculations upon the age of the earth have no value which are based upon the derivation of salt from the land through weathering processes and its accumulation in the sea, and which ignore or place as relatively unimportant the salt deposits of the land."

The final chapter of 240 pages deals with ore deposits and is an amplification and further systematization of the papers already published by the author in the Transactions of the American Institute of Mining Engineers. Special emphasis is placed on the application to ore deposits of all laws developed for metamorphism in general.

The foregoing pages of this review have served to give some

idea of the breadth and depth of this treatise. In conclusion it may be said that the general student will find here in the most systematized and digested form a vast mass of facts and principles dealing with chemical and physical geology. All students of geology should gain some familiarity with its contents, and to the specialist in metamorphism it must become a volume of constant study and reference.

J. B.

2. *The United States Geological Survey, Twenty-Fifth Annual Report, 1903-'04*, 371 pp., 25 pls., 2 figs.—The United States Geological Survey has reached its quarter-century anniversary and the director gives a brief outline of the results accomplished during the twenty-five years of the Survey's existence. A complete topographic map of 929,850 square miles of the United States, including Alaska, has been made during this time, which amounts to 31 per cent of the area of the country, excluding Alaska. The Survey has been particularly helpful in investigation of the origin and geologic relations of ore deposits; and the results of this work in Leadville and the Lake Superior region are alone sufficient to justify the generous appropriation now granted by congress. The first appropriation for the Survey amounted to \$106,000. The total appropriated in 1903-'04 was \$1,377,820. During recent years the qualitative standard of the work has been much raised; greater accuracy and higher literary quality characterize the recent papers published by the Survey. Eleven states now coöperate with the government in topographic surveys, and topography still claims the larger share of the annual appropriation.

The section of Pleistocene Geology has been renamed the section of Physiography and Glacial geology and placed in charge of G. K. Gilbert. This new division is in distinct recognition of the geographical aspects of geology, and the importance of ice as a geologic agent. The work in Alaska has received greater attention than ever before, and the geographic and geologic publications in that section show the development of one of the most remarkable pieces of scientific exploration ever attempted. The reclamation service reports rapid advance in many of the western states, and during the year actual construction was begun on the Salt River project in Arizona and the Truckee-Carson project in Nevada. The division of chemistry and physics is conducting important researches along new lines and it is gratifying to see that the work is sufficiently recognized as to receive largely increased appropriations.

3. *Geology of Perry Basin in Southeastern Maine*; by GEORGE OTIS SMITH and DAVID WHITE. United States Geological Survey, Professional Paper No. 35, 102 pp., 6 pls.—The Perry Basin has excited the interest of geologists ever since the formations were first described by Jackson in 1836, and a great deal of difference of opinion has existed regarding the origin and age of the strata here exposed. The formation is now shown to be "distinctly Devonian and probably Chemung." It consists of

brownish conglomerates with interbedded lavas lying unconformably on earlier formations.

The present investigation was undertaken jointly by the United States Geological Survey and the State of Maine in a search for coal, and ten days of field work were sufficient to amply prove that there is no geological evidence to support the belief that coal exists in this region. This investigation brings clearly to light the value of geologic work. For the last seventy years there has been a persistent belief that coal could be obtained in the district about Passamaquoddy Bay, and shafts and drill holes have been put down at considerable expense at different times. This persistent myth has led the public astray and shows how ready the average man is to accept favorable rather than unfavorable reports. At a small expense the question of coal in Maine has been settled once for all and might have been equally as well settled fifty years ago if it had been so desired.

In addition to newly discovered plant remains Dr. White has studied the collections in American museums, and his present descriptions and figures constitute a fairly complete study of the Perry fauna.

4. *Preliminary Report on the Arbuckle and Wichita Mountains of Indian Territory and Oklahoma*; by JOS. A. TAFF: with an appendix on *Reported Ore Deposits*; by H. FOSTER BAIN. United States Geological Survey, Professional Paper No. 31, 93 pp., 8 pls., 1 fig.—Very little has been heretofore known regarding these interesting mountain areas lying west of the main Ozark uplift. The Arbuckle Mountains consist of a great thickness of rock chiefly limestone, from Middle Cambrian to Devonian, overlaid by Carboniferous conglomerates, shales, and sandstones. The central part of the district, unconformably beneath the Cambrian strata, is a mass of granite, granite porphyry, diabase, and associated crystalline rocks. The mountains date from Middle Carboniferous, but were worn down before the end of Carboniferous time. Folding and faulting occurred during all Carboniferous, and there is no record of sedimentation between the Permian and Cretaceous. Peneplanation occurred in Cretaceous time and also in Tertiary, when the region was reduced practically to sea-level. The structure of the mountains has been worked out in detail and shows a number of well-developed anticlines and synclines.

The Wichita Mountains are a new field of study and consist of a collection of mountains, hills, and knobs extending for a distance of 65 miles. The mountain region is symmetrical in general outlines; but the arrangement, size, and forms of individual masses are remarkably various and rise from the nearly level smooth plain of the "red-beds" as so many islands. The mountains proper and most of their outlying groups consist of granite, granite porphyry, and gabbro. These igneous rocks are separated into more than 250 detached areas, and this archipelago-like arrangement of the granite peaks seems to indicate that but a

small part of the igneous core of the Wichita uplift is now exposed. The rock section of the Wichita Mountains is almost an exact reproduction both in stratigraphy and structure of the Arbuckle Mountain uplift, and the epochs of its stratigraphic history probably also correspond with those in the mountains to the east.

5. *The Oldest Sedimentary Rocks of the Transvaal.*—In a recent paper by FREDERICK H. HATCH, published in the Transactions of the Geological Society of South Africa, vol. vii, pt. 3, attention is called to the discovery of metamorphosed sediments of earlier age than the Witwatersrand series. The rock is variable in character. One of its striking features in the Mt. Marais district is the presence of "knotted" schist containing andalusite and ottrelite. This early formation has been named the Swaziland series and, with its intrusive granite, is ascribed to the Archean system. Swaziland beds occupy the same relative position as the Malmesbury beds of Cape Colony.

A paper by E. J. T. JOEBISSEN, read December 12th, before the Geological Society of South Africa, gives a detailed description of the granites which are intruded in the Swaziland beds, and underlying unconformably the Witwatersrand.

6. *Maryland Geological Survey. Miocene*, text, pp. i-clv, 1-543; volume of plates, x-cxxxv. The Johns Hopkins University, 1904.—These two splendid volumes treat of the stratigraphy and life of the Miocene deposits of Maryland. The stratigraphy is described by Clark, Shattuck, and Dall. The fauna and flora are described in detail and illustrated by excellent drawings, as follows: The plants, by Hollick and Boyer; vertebrates, by Case and Eastman; the bivalves, by Glenn; the other Mollusca, the brachiopods, and most of the Crustacea, by Martin; the ostracods and bryozoans, by Ulrich and Bassler; the echinoderms, by Clark; the corals, by Vaughan; the foraminifers, by Bagg. The number of fossil species is large, as 652 are described.

The State Geologist reports that the "most important contribution to the interpretation of the Maryland Miocene deposits which has been hitherto made" is by Dr. Dall. On pages cxxxix-clv, Dall discusses "The relations of the Miocene of Maryland to that of other regions and to the recent fauna." The Maryland Miocene is divided into Calvert, Choptank, and St. Mary's formations. "One-third of the molluscan fauna of the Maryland Chesapeake is peculiar to it. Ten per cent survive to the present fauna."

"The temperature conditions governing the fauna of the Maryland Chesapeake were those of the temperate rather than the boreal or subtropical faunas of the present coast; and . . . the temperature of the Chesapeake embayment was on the whole somewhat warmer than at present."

"In a general way, allowing for local peculiarities, the Miocene fauna of North Germany compares well and agrees closely with

that of Maryland, while the Mediterranean Miocene finds a closer analogue in the more tropical fauna of the Duplin beds of the Carolinas."

These volumes should be in the hands not only of stratigraphers and paleontologists, but of all teachers of historical geology as well, for here is given not only a detailed description of the Maryland Miocene stratigraphy and its preserved organic remains, but also the relationship of these faunas to those of other areas of North America and of Europe. The State of Maryland is to be congratulated on its able and active survey staff, under the efficient leadership of Professor W. B. Clark. Among state surveys it stands second, ranking next to that of the rich state of New York.

C. S.

7. *Palæontologia Universalis*. — The third fasciculus of this important republication of old or obscure species of fossil organisms has arrived. These three parts treat of 75 species, figured and described in 161 sheets. This completes the first annual subscription, which is eight dollars. The first fasciculus of the second series will soon appear, and subscriptions should be sent to G. E. Stechert and Co., 129-133 West 20th street, New York City. The editorial work is in the hands of D.-P. Ehlert, of Laval, France, Secretary to the International Commission appointed by the International Geological Congress, at its eighth meeting.

C. S.

8. *On the Melting Points of Minerals*. — M. A. BRUN has recently published a second memoir on the subject of the fusion of minerals, which was first discussed by him in 1902.* The object of the present investigation has been to establish the melting point of the feldspars and some other important minerals (leucite, chrysolite, wollastonite), both in the crystalline and glassy states. The results now obtained are summarized by the author as follows :

"The present work will serve to control scientifically the values previously given, and, also, to establish the melting points of the *colloids*, which have the same percentage composition as the crystals.

The measures have been taken with the help of the calorimeter. A large block of platinum was used as thermometer and Viole's rule was used for the calculation of the temperature.

The results of these experiments prove that the figures published in 1902 are exact. They therefore agree with the figures given for the *crystals*. It is shown, moreover, that in the complete thermic study of the silicates, the following points should be determined.

(a) The melting temperature of the *crystal*. (b) The melting and softening temperature of the *colloid* (glass) which has the same percentage composition. (c) The temperature needed to bring about the crystallization of colloids. (d) The temperature

* Arch. des Sc. phys. et nat. (4), xiii, April, 1902. See also the paper by Day and Allen in the February number of this Journal.

of the point of the agglomeration into a mass of powder such as : chrysolite, kaolin, zircon.

There are great differences between these various points. Between *a* and *b* there can be several hundred degrees of difference."

The following may serve as illustrations of the numerical results obtained.

For *anorthite* from Miyake Idsu, Japan, a crystal remained for a long time unaltered at 1350° ; at 1425° it still preserved its cleavage, and 1490° was obtained as the most probable point of the destruction of the crystalline structure. With *anorthite* of absolute purity, prepared for the purpose, the following values were obtained :

Relation of $\frac{c'}{c}$	Temp. of destruction of the crystal	Capacity in calories of 1 kilo of the fused mineral
7.07	1544°	451.2
7.1	1547°	453.6
7.128	1550°	455.9
7.19	1562°	456.8

For *anorthite* glass the following points were also obtained :

No. 2, Minimum temperature of the deformation of the glass, 1083° , 1110° .

No. 3, Temperature at which the glass begins to be clouded, 1144° .

No. 3 *bis*, Temperature at which the glass becomes crystalline, labile point, 1210° .

Temperature at which the crystallization has the appearance of being rapid, 1250° .

With *leucite*, at a temperature of 1430° the edges of the crystal were rounded and the faces vitrified though, as a whole, it did not lose its shape. At 1470° , though still preserving its form, it was softened so that it could be easily flattened out by the pincers. At 1500° the glass commenced to form and was complete at 1600° .

For *chrysolite* the point of fusion was too high to allow of being determined accurately but was estimated to be about 50° below that of platinum ; 1730° was taken as the probable temperature. *Wollastonite* from Auerbach (monoclinic in crystallization) was liquified at 1366° to a glass which quickly assumed a hexagonal crystalline structure. The artificial hexagonal mineral fused to a fluid, transparent glass at 1515° .

9. *Mineral Resources of the United States. Calendar year 1903.* DAVID T. DAY, Chief of Division of Mining and Mineral Resources. 1204 pp. 8vo. Washington, 1904 (U. S. Geological Survey, Charles D. Walcott, Director).—This annual volume of the Geological Survey devoted to the Mineral Resources of the United States, like its predecessors, contains a vast amount of useful and important information. This is made the more valuable from the fact of the admirable promptness with

which it is issued. Much of the matter, further, has already been in the hands of those interested in the form of separately issued pamphlets for the different chapters. The geologist-in-charge states that the report for the calendar year 1904 is already in course of preparation.

10. *Elements of Mineralogy, Crystallography and Blowpipe Analysis*; by ALFRED J. MOSES and CHARLES LATHROP PARSONS. Third enlarged edition. Pp. vii, 444, 8vo. New York, 1904 (D. Van Nostrand Co.).—The new edition of this convenient and useful text-book retains all the good features of the former issues, with some important changes and additions. The crystallography has been rewritten, various changes made in the part devoted to descriptive mineralogy, and the whole brought up to date, so far as statistics and similar matters are concerned. Numerous half-tones from photographs of mineral specimens are introduced; they are in some cases very satisfactory, but share the limitations of such illustrations in general.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Report of S. P. Langley, Secretary of the Smithsonian Institution for the year ending June 30, 1904*. Pp. 1-99. Washington, 1904.—The functions of the Smithsonian Institution are widely varied, including, besides publications and special work of research and exploration, the constantly expanding department of International Exchanges, the National Museum, the National Zoological Park, the Astrophysical Observatory and the Bureau of American Ethnology. This fact gives peculiar interest to the advance report of the Secretary in which the results accomplished for the year are enumerated. Among other points is to be noted the removal of the remains of James Smithson from Genoa, and their deposition in the Smithsonian Institution in the early part of 1904. Another point of interest is the beginning of the new Museum building for which ground was broken June 15, 1904. The new building will be some 551×318 feet and will give a floor area of $9\frac{1}{2}$ acres in its four stories. Some of the results obtained in the Astrophysical Observatory are given on p. 246 of this number.

The Bureau of American Ethnology, W. J. McGee, Acting Director, has recently issued Parts 1 and 2 of the 22d Annual Report. Of these Part 1 (pp. xliii, 320) contains the report of the Director to the Secretary of the Smithsonian Institution; also a paper by Jesse W. Fewkes (195 pp., 70 plates) on Pueblo Ruins; and one by Cyrus Thomas (pp. 197-305, 12 plates) on Mayan Calendar Systems. Part II (372 pp., 9 colored plates) is devoted to a memoir on the Hako, a Pawnee Ceremony by Alice C. Fletcher, assisted by James R. Murie.

2. *Report of the Superintendent of the Coast and Geodetic Survey, showing the Progress of the Work from July 1, 1903 to June 30, 1904*. 774 pp., with numerous plates and four maps.

Washington, 1904 (Department of Commerce and Labor).—The annual volume from the Coast and Geodetic Survey contains the general report of the Superintendent, Mr. O. H. Tittmann, for the year ending June 30, 1904, with special statements from the various assistants and inspectors. A series of nine Appendixes follow, giving the details of operations in the office and field, results of magnetic observations, of work done on telegraphic longitudes, on cotidal lines for the world and other subjects.

From the report by Mr. L. A. Bauer upon the results of the magnetic observations, we have quoted on another page (p. 248). The Superintendent notes the interesting fact of the completion of the determination of the difference of longitude between San Francisco and Manila, and details of the work are given by Assistant Edwin Smith in Appendix 4. It is notable that the finally accepted value of the longitude of the Cathedral dome at Manila differs but 0^o006 from that determined by officers of the U. S. Navy in 1881–82.

3. *The Scottish National Antarctic Expedition*.—The second Antarctic voyage of the "Scotia" has produced some interesting results. The Argentine government has agreed to take over the meteorological and magnetic observatory in the South Orkneys, established by the first Scottish expedition. The newly-discovered part of the Antarctic continent has been named Coatsland, in 74°1' south, 22°0' west. Some very rich hauls were made in 1410 fathoms of water in 71°22' south, 16°34' west, no less than sixty species of animals being obtained. One of the most interesting results of the exploration is the discovery that soundings made by Ross, and which are represented on practically all maps, are in error. Instead of a sounding of "4000 fathoms, no bottom" a sounding of 2660 fathoms was obtained, and the sea, likewise, is shown to be of much less extent than was supposed. Data were collected at the South Orkneys for a detailed map of Laurie Island; a continuous hourly meteorological record was kept for nine months; botany and geology were investigated, and an extremely rich shallow water fauna was collected. In the South Atlantic a somewhat deeper channel has been demonstrated between the Falkland Islands and the South Orkneys, and farther to the east the ocean maps have been materially changed by the discovery of a large southern extension of the Middle Atlantic ridge to the south of Gough Island.

4. *National Academy of Sciences*.—Vol. V of the Biographical Memoirs has been recently issued; it contains notices of the following gentlemen, former members of the Academy: Joseph Henry, John Edwards Holbrook, Louis François de Pourtalés, Augustus A. Gould, Henry A. Rowland, Theodore Lyman, Matthew Carey Lea, Francis A. Walker, John G. Barnard, James E. Keeler, James Hadley, Henry B. Hill, Sereno Watson, Robert E. Rogers. Each notice is accompanied by a portrait and signature.

5. *The American Museum Journal*.—The January number of this publication is largely devoted to a well illustrated paper by

W. D. Matthew on Fossil Carnivores, Marsupials and small Mammals in the American Museum of Natural History in New York City. Dr. E. O. Hovey also gives an account of the three Cape York meteorites, brought from Greenland by Capt. Peary, the two smaller ones in 1895 and the immense "Ahnighito" in 1897; these are now exhibited at the American Museum. The dimensions of the largest masses are: length, 10 ft. 10 in.; height, 7 ft. 2 in., and thickness, 5 ft. 6 in. The true meteoric nature of these masses is proved by the position in which they were found, as also by the characteristic composition as a nickel-iron alloy and by the octahedral crystalline structure developed by etching.

6. *Reflections suggested by the new Theory of Matter*; by the Right Hon. ARTHUR JAMES BALFOUR, M.P. 24 pp. London and New York, 1904 (Longmans, Green & Co.).—The Presidential address of Mr. Balfour, delivered before the British Association for the Advancement of Science at Cambridge, August 17, 1904, is highly interesting and suggestive, none the less so because the author views the problems of science not as an investigator but in a sense from the outside.

7. *Ideals of Science and Faith*, edited by J. E. HAND (Longmans, Green & Co.).—The first impression that strikes the reviewer in looking over this book is that the ancient feud between science and religion seems to have disappeared. In this volume there is grouped a series of essays by writers in widely diverse fields. The ideals of faith and science are discussed in separate essays, by Sir Oliver Lodge; Professors J. Arthur Thompson, John H. Muirhead, Victor V. Branford, Bertrand Russell, Patrick Geddes; Rev. John Kelman, Rev. Roland Bayne, Rev. Philip Waggett, and Wilfred Ward. Each of these authorities approaches the subject from his own particular view-point. The volume forms delightful reading for such as are interested in broader lines of intellectual development.

8. *Long-range Weather Forecasts*; by E. B. GARRIOTT. Prepared under direction of Willis L. Moore, Chief U. S. Weather Bureau. Washington, 1904 (Weather Bureau, Bulletin No. 322).—This bulletin should be widely read by the public at large, showing as it does how little foundation exists for the general credulity in regard to the possibility of making weather predictions for the distant future. The only suggestion as to probable progress in this direction is contained in the statement, "that advances in the period and accuracy of weather forecasts depend upon a more exact study and understanding of atmospheric pressure over great areas and a determination of the influences, probably solar, that are responsible for normal and abnormal distributions of atmospheric pressure over the earth's surface."

9. *English Medicine in the Anglo-Saxon Times; The Fitz-Patrick Lectures for 1903*; by JOSEPH FRANK PAYNE, M.D. Pp. 162, with sixteen plates. Oxford, 1904 (The Clarendon Press).—This volume contains the lectures, two in number, delivered by Dr. Payne before the Royal College of Physicians of London in June, 1903, somewhat extended by the introduction of

extracts from the works discussed and by other additions. They will be read with much interest by the layman, as well as by the physician, for they give a most interesting account of the early practice of medicine and surgery in England prior to the Norman Conquest, when this practice seemed to be largely based on the use of herbs and on superstition. The accounts given, with extracts, of the Leech Book of Bald and Cid (900-950) and of the Herbarium of Apuleius (1000-1050) deserve careful attention, as well as the representation of favorite plants, often in conventionalized and attractive artistic form.

10. *Studies in General Physiology*; by JACQUES LOEB. Decennial Publications of the University of Chicago, vol. xv. Chicago, 1905. In two parts, I, pp. 1-423; Part II, pp. 425-782. Advance sheets of this work have arrived as the present number is going to press; a notice is necessarily deferred.

11. *Early Stages of Carabidae*; by GEORGE DIMMOCK and FREDERICK KNAB. Springfield, Mass., 1904.—This memoir, illustrated by four plates, forms Bulletin No. 1 of the Springfield Museum of Natural History.

OBITUARY.

ALPHEUS SPRING PACKARD, Professor of Zoology and Geology in Brown University, died at his home in Providence, R. I., February 14, 1905, at the age of nearly sixty-six years.

Professor Packard was a son of the late Professor Alpheus Spring Packard of Bowdoin College, and was born at Brunswick, Me., February 19, 1839. He was graduated from Bowdoin in 1861, and from the Maine Medical School and the Lawrence Scientific School in 1864. At Cambridge he was one of that remarkable group of students—Hyatt, Morse, Packard, Putnam, Scudder, Shaler and Verrill—associated with the elder Agassiz in the early sixties. He served for a time in 1864-5 as Assistant Surgeon in the U. S. Army, but never became a regular practitioner of medicine, his life being devoted to his chosen work in zoology and geology. An enthusiastic field naturalist, collector, and explorer, as well as a very voluminous author who wrote on a remarkably wide range of subjects, he was specially distinguished as an entomologist. He is most widely known, and will probably be longest remembered, for his original work on insects and his several text-books on entomology and zoology. Early in his career he accepted the theory of evolution and later became an ardent neo-Lamarckian. One of his last works was, "Lamarck, the Founder of Evolution, His Life and Work." He was one of the founders of the *American Naturalist*, for twenty years its chief editor, and a constant contributor to its pages.

Professor Packard was a member of the National Academy of Sciences and of many European societies. Before his appointment at Brown in 1878, he was successively Librarian and Custodian of the Boston Society of Natural History, Director of the Peabody Academy of Science, State Entomologist of Mass., and a member of the U. S. Entomological Commission.

S. I. S.

T H E

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXIII.—*The Bearing of Physiography upon Suess' Theories*;* by W. M. DAVIS.

CONTENTS:—Three conclusions reached by Suess. Observations on the Tian Shan Mountains and on the Steppes north of the Tian Shan. Penetration of these regions, followed by uplift of the mountains. The existing Tian Shan ranges are not demonstrably the result of tangential movement toward the south. Other examples of mountains carved in uplifted peneplains. Suess' theory of horsts; the great area of subsidence that it requires. Improbability that horsts have stood still while all the rest of the earth subsided. Horsts are probably the result of local uplifts, while all the rest of the earth remains relatively undisturbed.

THE eminent Austrian geologist, Professor Eduard Suess, has emphasized three conclusions of his researches. Uplifts are limited to mountain belts, where tangential pressure has acted to produce a resultant uplifting force; mountain ranges are of unsymmetrical structure, as a result of tangential movement, and not symmetrical as a result of axial uplift; plateau-like masses owe their altitude, not to their own uplift, but to the subsidence of the surrounding lower areas. Although displacements are elaborately discussed, it is notable, as has been pointed out by various students of Suess' works, that he gives only a minimum of attention to the processes and results of erosion, whereby so many features on the face of the earth have been given their actual expression. The present article offers some considerations on this aspect of the subject, and leads to conclusions that differ from those reached by Suess.

As a member of Professor Raphael Pumpelly's Carnegie Institution expedition to Turkestan in 1903, I had opportunity of crossing the western ranges of the Tian Shan mountain system, where the occurrence of a curious flat-topped range,

* Revised, January, 1905, from a paper presented before the Eighth International Geographic Congress in Washington, September, 1904.

AM. JOUR. SCI.—FOURTH SERIES, VOL. XIX, NO. 112.—APRIL, 1905.

the Bural-bas-tau, in the neighborhood of Son-kul (lake), attracted my attention. Its plateau-like surface was heavily snow-covered at an altitude of 12,000 or 13,000 feet or more; its northern flank was deeply gashed with deep ravines heading in glacial cirques; the rocks exposed in the cirque walls and in the sharp arêtes between the ravines seemed to be massive crystallines, but as my observations were made with a field-glass at a distance of ten or fifteen miles, this point will not be insisted upon. Yet in any case there was no indication of horizontal structure, with reference to which the even highland surface might have been determined. I have published a brief account of the range in *Appalachia* (x, 1904, 277-284). There is no question in my mind that the plateau-like mountain top is a displaced fragment of a peneplain, and hence that its present highland surface is the work of erosion at a comparatively moderate height above baselevel of an earlier time.

Other ranges in the Tian Shan system exhibit similar displaced or tilted blocks of a peneplain, though none of them that I saw are so remarkable in this respect as the Bural-bas-tau, whose highland combines the features of exceptional smoothness, great altitude, and unusually good preservation. The Alexander range, west of Issik-kul, seemed to be a tilted block, with a gentle slope to the south independent of structure, and an abrupt descent to the north. The western end of the Kungei Ala-tau, north of Issik-kul, was of plateau-like form. It is noteworthy that when the even highland of the western part of this range is projected eastward, it seems to rise above the serrate summits of the rest of the range. The same is true regarding the westward prolongation of the highland in the Bural-bas-tau. Both these examples therefore suggest that certain ranges of Alpine form, in which the sharp peaks now give no indication of having been carved from a flat-topped mass, may nevertheless have had precisely such an origin. It is also to be noted that in these cases the relation of the serrate peaks to the even highland is not such as to suggest that the former are recarved residuals that once rose above and more or less completely surrounded the latter. Other examples of ranges that indicate former peneplanation are described in my part of Professor Pumpelly's forthcoming report. All these ranges seemed to be isolated and dissected blocks of a broken peneplain.

Between Viernyi and Semipalatinsk (northeastern Turkestan and southern Siberia), I crossed many miles of rolling steppe of small relief and of moderate altitude above sea-level. Parts of this extended surface came nearer to the realization of a low-lying peneplain than anything that had previously come under my observation, yet even there the surface was prevail-

ingly undulating, so that laterally swinging rivers can have had little share in its production: the only exception to this rule was in the immediate neighborhood of the Irtysh river, whose lateral swinging may have there been effective. The rocks were crystallines or disordered sedimentaries, and the gently undulating surface was evidently the result of long continued subaërial erosion. Here and there mountains rose; some of them seemed to be residual masses, as they had undulating skylines; others seemed as clearly to be isolated blocks of the peneplain, as they possessed uplands of remarkably even form. The conclusion thus grew upon me that the whole region, mountains and steppes alike, had once been greatly worn down, although it probably retained strong monadnocks here and there; and that the mountain ranges which we see to-day had been afterwards uplifted in blocks of greater or less extent; the residual eminences of the former cycle presumably form the loftiest peaks that rise above the present highlands.

This conclusion was strengthened on receiving the report of my companion, Mr. Ellsworth Huntington, who had turned southward from Issik-kul and crossed the Tian Shan to Kashgar. He found large plateau-like highlands of deformed structure and moderate relief surmounted by occasional higher eminences, monadnock-like, and deeply dissected by steep-sided valleys, and he was thus convinced that these highland areas had gained their altitude relative to sea level in comparatively recent time, after prolonged erosion: he describes the Tian Shan, where he crossed it, as "potentially but not actually mountainous." Farther eastward, however, the dominating mass of Tengri-khan is actually mountainous in a high degree: it may be provisionally regarded as a reëlevated surviving mountain group of the former cycle. On looking over the reports of other observers after my return home, several brief descriptions of the plateau-like aspect of the Tian Shan highlands were found; but the only account which interprets their meaning is by Friedrichsen, a pupil of Richtshofen's, who visited the region in 1902, and who is now docent in geography at Göttingen: his articles unfortunately came to my notice only after my return from Turkestan. He recognizes the even highland which he saw southeast of Issik-kul to be a formerly lower-lying *Denudationsfläche*, now displaced and exposed to revived erosion, but thinks it may have been worn down with respect to a local baselevel in a relatively enclosed basin (Petermann's Mitteilungen, xlix, 1903, 136), and hesitates to express an opinion as to the area over which correlated peneplains once extended.

In view of these interpretations, it seems inadmissible to follow Mushketof and Suess in regarding the Tian Shan as a

mountain range due to lateral pressure. Its rocks may certainly have suffered compression in some past age, for they not infrequently exhibit deformation of the kind that geologists accept with good reason as evidence of the action of tangential forces. Furthermore, the region may in some past time have risen to mountain heights as a result of such compression, for it seems reasonable to associate superficial disorder and elevation with crustal compression, whether the work of compression be superficial or deep-seated. But the time when compression deformed the rocks and when the region rose in mountain form as a result of such compression must now be long past, because the even surfaces or peneplains of the highlands and the steppes truncates the disordered structures, and thus proves that a long period of erosion—in effect, a physiographic cycle—has elapsed since the compression took place; and to this period must be added the early part of another cycle, sufficient for the dislocation, elevation and partial dissection of the peneplain and its residuals of the first cycle. The ranges that my path crossed were so largely composed of massive crystalline rocks that it is impossible for me to state what relation generally exists between the trend of the existing ranges and the strike of the deformed strata: in one small range, the trend of the crest and the strike of its steep dipping beds diverged at a strong angle; in another case, there was rough coincidence between range trend and strike of slaty cleavage; both these ranges gave good indication of having been worn down to low relief before their present altitude was gained. It is, therefore, not now possible to say what relation exists between the reliefs of the original ranges, due to compression, and the existing ranges, due to some other kind of displacement.

Whether the peneplain fragments seen in the existing ranges and the broad peneplain of the steppes were once parts of a single very extensive peneplain, or whether they represent parts of neighboring but isolated peneplains, need not now be further considered—particularly as the facts needed to settle this question are not yet in hand. It is sufficient to note that the actual attitudes of the peneplain fragments, large and small, now seen in the Tian Shan ranges are not such as to indicate the direct action of forces of horizontal compression. It is true, as above intimated, that one may suppose the dislocation of the mountain blocks to be the superficial result of a deep-seated compression; but our ignorance of the processes that go on within the earth is so profound that a speculation of this kind has no compulsory value; it certainly does not entail the classification of the existing Tian Shan system in the group of mountains due to forces of lateral compression. Hence the Tian Shan should not, in my

opinion, be adduced as an example of "tangential movement directed toward the south" (Suess, *Das Antilitz der Erde*, i, 603; French translation, i, 619), nor should its topographic arrangement be taken to support the thesis that a certain curvature of ranges and a certain disposition of steeper slopes, noted in various mountain systems and described for the Tian Shan by Mushketof, are either the result of or the index of tangential pressure. The Tian Shan appears to be the result of displacements that have taken place in part of a very extensive degraded region: as a consequence of the displacements, large areas, that were previously below the reach of effective attack by streams, have come to be high above baselevel, so that they are exposed to the most energetic erosion. Having lived nearly through one cycle, they have now entered a second cycle of mountain sculpture; but there is no clear reason for thinking that forces of compression rather than forces of uplift have acted to renew their mountain height.

The case of the Tian Shan is less exceptional than it may appear at first sight. It is now nearly thirty years since Gilbert announced that forces of uplift, perhaps involving horizontal extension, and not forces of horizontal compression, gave the best explanation of the Basin ranges of Utah and Nevada. At a later date, various other ranges in the United States came to be regarded as uplifted masses, with more or less warping or tilting, but without recognizable compression, because their even crest lines or highlands appeared to be the result of peneplanation in an earlier cycle of erosion: the Sierra Nevada in California and the Appalachians in the Atlantic States were among the first to be thus explained; since then, the Cascade and the Coast ranges of Oregon and Washington have been similarly treated, and Gilbert has lately given an account of a lofty and dissected peneplain in the mountains of Alaska. In the meantime, similar results have been reached in Europe. The highland fjelds of Norway are now treated by Reusch and others as having been reduced to moderate relief by long-continued erosion during a lower stand of the land, and afterwards given a greater elevation: there is no indication that their present altitude has been gained by crustal compression. More recently, de Martonne has announced a similar sequence of events for the Carpathians, and Penck has done the same for the Alps. Willis' recent explorations in China led him to similar results regarding extensive mountainous tracks in that far-off country. It was indeed a matter of special interest to the physiographers who attended the International Geographic Congress last autumn to hear the independent testimony of these three observers to the effect that the ranges which they described did not owe their present altitude to forces of compression, however much

their rocks may have been horizontally crushed in some earlier period of deformation; for in all three cases the mountainous areas were described as having been worn down to moderate relief after their rocks had been deformed, and their present altitude was explained as having been gained subsequently, by displacements from which the accepted characteristics of compression were absent. In none of the examples here adduced was particular attention paid by the investigators above named to the features of asymmetry and curvature of mountain tread, upon which Suess lays importance; hence that phase of his theory is not here further considered; but in so far as the present relief of the ranges mentioned is concerned, it should not, if the explanation by non-compressional displacement is correct, be ascribed to or correlated with tangential movement, however fully the internal structure of the ranges may be thus accounted for. My own observations on the Tian Shan had led to essentially the same conclusions, as already stated.

The nature of the forces by which displaced fragments of peneplains have gained their present altitude is not at once apparent, but the following considerations lead to the belief that forces of uplift may have acted in giving such ranges as the Bural-bas-tau and its fellows their actual elevation. If it be agreed that the highlands of the Tian Shan are parts of a once relatively low-lying peneplain, and that their present attitudes exclude lateral compression as a cause of their present altitude, then two contrasted explanations may be offered to account for the crustal displacement by which the rivers of the region have been excited to deep erosion of the surface that was previously safe from their attack. It may be supposed, on the one hand, that the whole region once had the altitude of the Bural-bas-tau highland and its fellows, and that since then the now lower parts of the region have subsided to the present levels; or, on the other hand, that the whole region once had an altitude similar to that of the steppes between Viernyi and Semipalatinsk—with as many and as strong monadnocks and residual ranges as further observation shall demand—and that since then the higher parts of the region have been uplifted. The first supposition is the view adopted by Suess and by a number of European geologists; the second is the view generally accepted by American geologists, as well as by some Europeans. I have not been able to devise any means of making absolute choice between the two views, but it seems to me that many reasons may be adduced for the probable correctness of the second view rather than of the first.

The theory of subsidence may be called the theory of *horsts*; *horst* being a mass of earth-crust which is limited by faults and which stands in relief with respect to its surroundings. The Harz mountains in northern Germany and the central plateau

of France may be mentioned as smaller and larger examples in Europe; the plateaus of northern Arizona are examples in this country. *Graben* are the reverse of horsts, being fault-bounded areas that stand below their surroundings. The valley of the middle Rhine is a famous European example: the troughs of certain of the great African lakes, described by Gregory as "rift-valleys," are also *graben*. According to Suess' analysis of the problem, the movements which produce horsts and *graben* "are easily explained, in the absence of tangential movements, by a yielding of the support and by the force of gravity. Everything of this kind that one observes is only a variation on passive settling or sinking" (*Das Antlitz der Erde*, i, 165; French translation, i, 162). "Great plains may sink down; as soon as their support yields, they obey the action of gravity; but we know no force capable of uplifting, unequally and locally, mountainous masses situated side by side" (*ibid.*, i, 736; i, 775). He continues, there are two facts which we cannot escape: the first is that "large areas have simply sunk down under the influence of gravity. The second is that no force is known capable of uplifting numerous great and small mountainous masses vertically and independently, between two plane surfaces, and of sustaining them in this uplifted position permanently, in spite of gravity" (*ibid.*, i, 741; i, 782).

With all the respect that one must feel for the erudition of such a master of the geology of the whole earth as Suess has shown himself to be, the conclusions indicated in the above extracts do not seem to me to be proved. The faults by which horsts and *graben* are bounded truly show a differential movement, more or less nearly vertical, but the means of determining, independently of all theory, which mass went up or which mass went down are, to say the least, obscure. The observed facts of dislocation taken alone are consistent with various suppositions as to the movement of the adjoining masses: both may have moved upwards, one more than the other; both may have moved downwards, one more than the other; one may have stood still, and the other may have moved; both may have moved, one upward, the other downward. It is not satisfactory to appeal to our ignorance of available forces of uplift and support as a mean of choosing among these alternatives: the operations of the earth's interior are so little understood that we are as much in the dark about their action as they are. Nor does the accumulation of examples that may be explained by subsidence strengthen the case, unless it is shown at the same time that they cannot be explained by upheaval. The actual movement of faulted masses can be rigorously determined only by relating them to some fixed standard of comparison, and that is no easy task. It seems hopeless in the present state of our knowledge to speak of movements with respect to the earth's center; for the sea-surface and not the earth's center is our

only standard of comparison. It is at best a movable standard, yet in the present problem it will fairly serve our purpose.

So far as I have been able to learn, the horsts described by Suess are not examined to discover how far the form of their surface may give indication of the altitude that they possessed with respect to sea-level before the occurrence of the faults by which they have been placed in relief : yet such an examination is well worth while. In the case of the Schiefergebirge of the middle Rhine, for example, the form of the upland is for the most part that of a well-developed peneplain, more or less warped, here and there surmounted by residual monadnocks, and now dissected by valleys. This district, therefore, stood at a moderate altitude above sea-level, before its present altitude was gained. Hence, if the present altitude were gained by the subsidence of the surrounding lower lands, we are constrained to believe that not only the surrounding lower lands, but all the oceans went down as well, and all the continents with them—the Schiefergebirge and the neighboring uplands alone standing still. The same is true of the plateau of northern Arizona, across which the Colorado has cut its precocious canyon : the plateau is a surface of denudation, and according to the most reasonable interpretation was once a lowland of small height above sea-level : if its present altitude has been passively gained by the subsidence of the surrounding lower districts, then in this case again all the oceans must also have gone down, and the rest of America and the other continents with them. Many more examples of the same kind might be mentioned, but the most impressive one that has come under my own observation is the Bural-bas-tau. It seems extravagant to suppose that all the rest of the lands and seas had to sink by some 10,000 feet in order to leave that range and its fellows in strong relief.

It is not intended, however, to imply that every horst was formed by a separate subsidence of all the rest of the world, for in so far as peneplained horsts are of the same date of production and of the same altitude, one subsidence of the rest of the world will suffice for their production ; but many of the known examples of such horsts are in very different stages of dissection, and they stand at different altitudes ; hence various widespread subsidences must, according to this theory, be admitted in order to account for them. It is not clear to me whether this world-wide extension of subsidence has been considered by Suess : it does not seem to be explicitly excluded in his writings ; it may be that it is tacitly accepted, to be more fully treated in later volumes : he says indeed, in discussing changes of level in the Rocky mountains, “we shall have to return to questions of this kind, and I hope then to be able to show that there is need of correcting more than one wide-

spread opinion concerning the position of sea-level in epochs anterior to ours" (*ibid.*, i, 740; i, 782). For my own part, I know of no complete disproof of the theory of subsidence, enormous as its demands appear to be. It is in a certain sense conceivable that the Bural-bas-tau stood still, like a post in a frozen pond, while all the rest of the world went down two miles, like the sinking ice when the pond water is drawn off—this being an analogy suggested by Suess himself (*ibid.*, i, 736; i, 774); nevertheless, in the absence of definite knowledge as to the mechanics of the earth's interior, it seems legitimate to entertain some more economical alternative hypothesis whereby the Bural-bas-tau and its fellows were locally uplifted about two miles from their former lowly estate, as a result of relatively local deep-seated movements of the earth's under mass, about which the great body of the earth knew little. How these deep-seated movements may be caused, it is impossible now to say. Two methods of search may lead to the discovery of their origin and character: one method proceeds partly from general facts as to the density, temperature and composition of the earth, and partly from general speculations as to cosmical history and the evolution of the earth; the other proceeds from special facts as to the deformations that the earth's surface has suffered, with abundant detail as to time and place. In briefer phrase, one method seeks to determine the character of the earth's internal movements from their causes; the other, from their effects. It will probably be long before either or both methods reach a solution of so recondite a problem. In the meantime, it seems advisable to take the sea-level as our standard of reference, and to speak of now high-standing isolated penepains as locally uplifted, all the rest of the world remaining relatively undisturbed, whether the forces that produce the uplift are explained or not.

Similarly, a graben may be spoken of as a sunken area, when there is evidence that its position with respect to sea level had been lowered, as would appear to have been the case with the floor on which the Triassic beds of Massachusetts and Connecticut were deposited; but in such examples as the Rhine graben it does not seem legitimate to measure the amount of sinking from the level of the high-standing penepains in the highlands on the east and west.

In all these cases of local change the sea surface may be provisionally regarded as fixed. A change in the level of the sea must be universal, synchronous and of equal amount (except for concomitant local changes in a land mass) along all shore lines. A universal change should be accepted only when demanded by widespread and accordant evidence, such as Suess has in so masterful a manner brought forward in the case of the world-wide Cretaceous transgression.

ART. XXIV.—*On the Progress of the Albatross Expedition to the Eastern Pacific*; by ALEXANDER AGASSIZ.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Chatham Island, Jan. 6, 1905.]

WE left Callao for Easter Island Saturday afternoon, December 3; as far as 90° west longitude we remained in the Humboldt current, as we could readily see from the character of the temperature serials and from the amount of pelagic life we obtained from both the surface and the intermediate hauls. This current also affected the bottom fauna, which was fairly rich even as far as 800 miles from the shore while we remained within the limits of the northern current. As soon as we ran outside of this the character of the surface fauna changed; it became less and less abundant as we made our way to Easter Island, the western half of the line from Callao becoming gradually barren. This current also affected the deep-sea fauna to such an extent that towards Easter Island, at a distance of 1,200 to 1,400 miles from the South American continent, our trawl hauls were absolutely barren; the bottom of the greater part of the line was covered with manganese nodules on which were found attached a few insignificant siliceous sponges, an occasional ophiuran, and a few brachiopods or diminutive worm tubes, the same bottom continuing to Sala y Gomez and between there and Easter Island. Sala y Gomez and Easter Island are connected by a ridge on which we found 1,142 fathoms near Sala y Gomez, and 1,696 fathoms between that point and Easter Island. The ridge rises rapidly from about 2,000 fathoms, the general oceanic depth within about 100 miles, to over 1,100 fathoms within a comparatively short distance from both Sala y Gomez and Easter Island.

The southern part of our line from Easter Island to the Galapagos shows all the features characteristic of the western part of the line from Callao to Easter Island; like the latter, as far as the 12th degree of southern latitude it proved comparatively barren, the bottom consisting of manganese nodules to within about 250 miles of the Galapagos. The pelagic and intermediate fauna from Easter Island to 12° south latitude was very poor, and the serial temperatures show that we were outside and to the westward of the great Humboldt current. But near the 12th degree of southern latitude a sudden change took place; the pelagic and intermediate fauna became quite abundant again and soon fully as rich as at any time in the Humboldt current. There was also a marked change in the temperature of the water as indicated by the serials, showing that from the 12th degree of southern latitude to the Galapagos we were cutting across the western part of the Humboldt

current. The great changes of temperature which took place in the layers of the water between 50 and 300 fathoms are most striking, and show what a disturbing element the great mass of cold water flowing north must be in the equatorial regions of the Panamic district to the south and to the north of the Galapagos. South of the Galapagos the western flow of the Humboldt current must be nearly 900 miles wide, and of about the same width when running parallel to the South American coast.

The range of temperatures between 30 fathoms and 150 fathoms is at some points as great as 21° . Such extremes cannot fail to affect the distribution of the pelagic fauna, and may account for the mass of dead material often collected in the intermediate tows at depths of less than 300 fathoms, when the range becomes as great as 28° . Such a range of temperature is far greater than that of the isocrymic lines which separate coast faunal divisions. The bottom fauna, as we entered the Humboldt current going north, gradually became richer in spite of its being covered with manganese nodules.

The two lines centering on Easter Island developed the Albatross Plateau indicated on the Challenger bathymetrical charts, on the strength of a few soundings reaching from Callao in a northwesterly direction and of a couple of soundings on the 20th degree of latitude. The Albatross Plateau is marked as a broad ridge separating the Buchan Basin from the deep basin to the westward, of which Grey Deep and the Moser Basin are the most noted areas.

Our line from Easter Island to the Galapagos showed a wonderfully level ridge, varying in depth only from 2,020 to 2,265 fathoms in a distance of nearly 2,000 miles. The soundings we made to the eastward from the Galapagos to the South American coast, and to the westward of Callao, as well as on the line from Callao to Easter Island, all indicate a gradual deepening to the eastward to form what the Challenger has called the Buchan Basin with the greatest depths of 2,400 to over 2,700 fathoms and passing at several points near the coast to Milne-Edwards Deep, Haeckel Deep, Krümmel Deep, and Richards Deep, some of them with a depth of over 4,000 fathoms. According to the Challenger soundings the Juan Fernandez Plateau connects with the Albatross Plateau and forms the southern limit separating Buchan Basin from the Barker Basin to the south of the Juan Fernandez Plateau.

At Easter Island we found our collier awaiting our arrival. We moved from Cook Bay to La Pérouse Bay to coal, as there was less swell there than in Cook Bay, where we could scarcely have gone alongside for this purpose.

Considerable shore collecting was done at Easter Island. We must have brought together at least 30 species of plants. The flora of Easter Island is very poor. There are no trees

nor native bushes—not even the bushes which characterize the shore tracts of the most isolated coral reefs of the Pacific are found there; and yet some of the equatorial counter-currents must occasionally bring some flotsam to its shores. We collected a number of shore fishes and made a small collection of the littoral fauna. The fishes have a decided Pacific look, and the few species of sea-urchins we came across are species having a wide distribution in the Pacific.

While coaling, we spent some time examining the prehistoric monuments which line the shores of Easter Island. During our stay at La Pérouse Bay we visited the platforms studding the coast of the bay, and made an excursion to the crater of Rana Roraka, where are situated the great quarries from which are cut the colossal images now scattered all over the island, many of which have fallen near the platforms upon which they were erected. Near Rana Roraka, at Tongariki, is the largest platform on the island, about 450 feet in length, to the rear of which are 15 huge images which have fallen from the pedestals upon which they once stood. The plain in the rear of the platform is crowded with stone houses, most of which are in ruins.

On our return to our anchorage at Cook Bay, we examined the platforms within easy reach of the settlement, and also the crater of Rana Kao, on the north rim of which, at Orongo, are a number of the stone houses built by the people who quarried the great stone images. At Orongo are also found sculptured rocks, but neither the sculptures nor the images show any artistic qualities, though the fitting of some of the cyclopean stones used in building the faces of the platforms indicates excellent and careful workmanship. To Mr. C. Cooper, manager of the Easter Island Company, we are indebted for assistance while visiting the points of interest of the island. He was indefatigable in his exertions in our behalf.

We took a number of photographs during our stay, illustrating not only the prehistoric remains, but giving also an idea of the desolate aspect of Easter Island during the dry season.

We arrived at Wreck Bay, Chatham Island, Galapagos, on the 3d of January, where we found a schooner with a supply of coal. As soon as the ship has been overhauled and coaled we shall start for Manga Reva, where we ought to arrive the last days of January. We reached Chatham Island towards the end of the dry season. Everything is dried up; the vegetation seems dead with the exception of a few small wild cotton plants, weeds, cactus, and an occasional mimosa; and the great barren slopes present fully as uninviting an aspect as when Darwin described them. When the Albatross visited the Galapagos in March, 1891, everything was green, presenting a very marked contrast to its present desolate appearance.

ART. XXV.—*Replacement of Quartz by Pyrite and Corrosion of Quartz Pebbles*; by C. H. SMYTH, JR. (With Plate II.)

I. Replacement of Quartz by Pyrite.

THE lowest beds of the Oneida conglomerate, in Central New York, are characterized by the presence of considerable pyrite, serving as a cement to bind together the quartz grains and pebbles of which the rock is mainly composed. The relations between the two minerals are worthy of note.

The quartz is, of course, clastic, while the pyrite has been deposited from solution, and would naturally be expected simply to fill the interstices between the more or less perfectly rounded grains of the former mineral, as is the case with the secondary quartz cement of the upper beds of conglomerate.

The pyrite, however, behaves quite differently. Instead of being molded upon the quartz grains and taking its shape from them, the reverse relation holds good, and the form of the pyrite is deeply impressed upon the quartz grains, giving them angular, jagged and pitted contours, totally unlike their original clastic forms. That these contours are secondary and conditioned by the pyrite, admits of no doubt; for not only is the shape of the grains wholly incompatible with water transportation, but, when sections are examined in detail, it is evident that the outlines of the quartz grains are commonly determined by crystal faces of the pyrite, the latter mineral occurring with its own forms, pyritohedron and cube, to which the older quartz has been forced to accommodate itself. In other words, the surfaces of the quartz are such as would have resulted had it been deposited from solution upon the already crystallized pyrite, which is just the reverse of the actual relation. The pyrite seems to have crystallized as readily as though filling open spaces or pushing aside some soft medium, like clay, instead of forcing its way into so refractory a substance as quartz; and, in consequence, the quartz grains are bounded, not by their normal, water-worn surfaces, but by variously oriented minute planes, conforming to the crystal faces of pyrite. Between such grains and those showing their original contour there is a complete gradation, and some of the latter are surrounded by pyrite. But this is decidedly exceptional, the pyrite nearly always eating its way to a greater or less distance into the quartz, while in the absence of pyrite the quartz retains its original form.

Some idea of these various features may be gathered from the accompanying photomicrographs (Plate II). Although

affording a very unsatisfactory substitute for actual sections under the microscope, they suffice to show that the relation between the two minerals is quite different from that ordinarily subsisting between clastic quartz grains and their cement, and can be explained only as resulting from the simultaneous solution of quartz and deposition of pyrite, or, in other words, the metasomatic replacement of quartz by pyrite.

The amount of replacement varies considerably, even within the limits of an ordinary thin section, and sometimes a grain of quartz is considerably replaced on one side, showing the jagged contour impressed by the pyrite, while the other side retains the clearly defined original outline. Figures 1, 5 and 6 (Plate II) show cases of this kind, where the replacement is in early stages and the grains retain their original outlines to some extent, although the pyrite has eaten into them considerably. In figures 2 and 4, on the other hand, few traces of the original margins of the grains are left.

Thus far, in spite of the variation in the amount of replacement, no section has been seen which contains pyrite and does not show replacement. Even where there are but a few scattered crystals of pyrite, they have eaten into the adjacent quartz just as in parts of the rock that are strongly pyritiferous (fig. 1). Sometimes such isolated crystals, and even larger masses of pyrite occur entirely within quartz grains, having, doubtless, been deposited from solutions entering cracks. It is evident, however, that, as a rule, the replacement started at the surfaces of the grains.

This is a matter of interest in its bearing upon the history of the replacement, as it shows plainly that the solutions effecting the change circulated through the beds of sand and gravel before they were cemented. For, had these beds been indurated, as the upper beds are now, by secondary quartz, filling the interstices between the grains, any replacement that might have followed would have been controlled by secondary surfaces, resulting from fractures subsequent to cementation, and would show no such dependence upon the original surfaces of the quartz grains.

Such openings as escaped complete filling by pyrite were subsequently closed by secondary quartz. It is evident that when this happened the quartz would take the form of the pyrite, and thus give a texture identical in appearance with that described above. This relation is shown in figures 3, 5 and 6, and may be seen frequently in the sections, but it is always a minor feature; and while, in photographs with low powers, it might be confused with replacement, when seen under the microscope, the results of the two processes are easily distinguished, as they are in figures 5 and 6. There might be some

doubt in the case of very small grains, but with reference to the general relation of quartz and pyrite in the rock, secondary quartz is an entirely negligible factor.

As to the relative amounts of interstitial filling and of replacement, the evidence is quite clear. In the non-pyritiferous rock, the quartz grains are very closely packed and the interstitial filling correspondingly slight, but in the pyritiferous beds the quantity of pyrite between the grains is often considerable. The amount of replacement is greater or less according as the original interstitial space was large or small. While sometimes well-rounded grains are widely separated by pyrite, much the commoner case is the occurrence of jagged contours, and when parts of the original surfaces remain, it is evident that their complete restoration would largely take up the space now filled by pyrite (figs. 5 and 6).

This is repeated so often that it is deemed excellent evidence for believing that the original sand was closely packed, like that of the overlying beds, with small interstitial cavities, and that the considerable space now occupied by pyrite is due chiefly to replacement. According to this view, figures 2, 3 and 4 represent later stages in a process whose earlier stages are represented by figures 1 and 5.

If the space now filled by pyrite were regarded as original, it might be concluded, as there is no reason for assuming the former presence of any other cement, that the sand and pyrite were deposited simultaneously, the pyrite coating the grains and thus keeping them from being closely packed. Primary deposition of pyrite in sediments is common, an instance described by Rensch* being of particular interest in this connection; and this explanation is favored by the apparently fixed stratigraphic position of the pyrite, and the fact that it was deposited before the secondary quartz. But if the foregoing interpretation of the texture of the rock is correct, a later introduction of the pyrite is indicated; although, so far as the evidence goes, it may have followed closely upon the deposition of the sand and gravel, while they were still exposed upon the sea bottom. This latter view, which is but a slight modification of the preceding, would account equally well for the position of the pyrite and for its deposition before the secondary quartz.

While it is a general rule that the primary pyrite of sediments is deposited in the presence of abundant organic matter, which is lacking in the conglomerate, the underlying Lorraine formation would be a possible source of hydrogen sulphide and other reducing agents.

* Neues Jahrbuch f. Mineralogie, etc., 1879, p. 255.

Thus, so far as the pyrite itself is concerned, there is reason for thinking that it was deposited in the gravel and sand lying uncovered on the sea bottom. But, on the other hand, it is difficult to believe that, had the pyrite been so deposited, there would have been any replacement of quartz. Such metasomatic processes usually take place after rocks are deeply buried, and subjected to the action of underground waters; and while, in the case of a readily soluble mineral, such as calcite, sedimentation and replacement are often practically simultaneous, with our present limited knowledge of the chemical reactions on the sea bottom, it seems unlikely, in spite of the evidence given later as to the solubility of quartz under surface conditions, that this would be true of quartz. Thus, it appears probable that the replacement of quartz by pyrite was effected by ground waters, rather than by chemical reactions coincident with, or directly following, the deposition of the sand and gravel. But as this conclusion is based upon general considerations rather than upon direct and positive evidence, it may be modified by future investigation.

As to the bearing of the stratigraphic position of the pyrite upon the above conclusions, it should be said that, owing to the unsatisfactory exposures of the formation, there is much to be learned with reference to the precise distribution of the pyrite, and it is certain that the higher beds often contain enough of the mineral to weather yellow, brown and black. It seems, therefore, unwise to lay great stress upon the stratigraphic position until it is more accurately determined.

However, even if the pyrite is largely confined to a definite horizon, at the bottom of the conglomerate, it is possible to reconcile the fact with the above conclusion as to its secondary origin. Before cementation, the conglomerate must have been a permeable formation, permitting a free circulation of water. Immediately beneath it, on the other hand, the fine-grained Lorraine formation would be relatively impervious, and thus, along the contact, or in the bottom beds of the conglomerate, the conditions would be favorable for deposition. These beds might be quite uniformly impregnated with such a mineral as pyrite, which, in consequence, would have a definite stratigraphic position, in spite of its secondary origin.

With so much that is uncertain, it is not worth while to make any attempt to explain in detail the chemistry of the deposition of pyrite and replacement of quartz, but it is natural to suppose that hydrogen sulphide and iron and alkaline carbonates were active agents in the process. These compounds are sufficiently common in ground-waters to warrant the assumption of their former presence where effects are observed of which they would be a probable cause, although there are

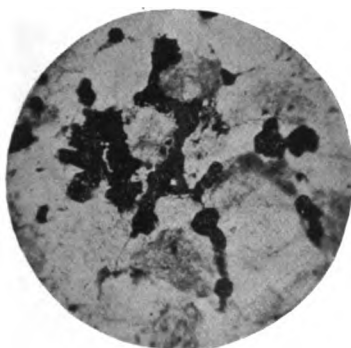


Fig. 1, $\times 26$ diam.

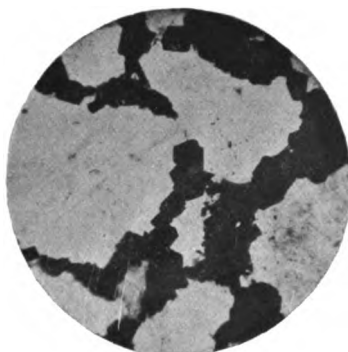


Fig. 2, $\times 26$ diam.



Fig. 3, $\times 26$ diam.

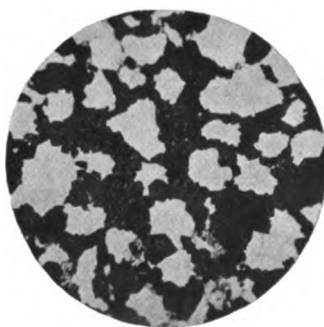


Fig. 4, $\times 23$ diam.

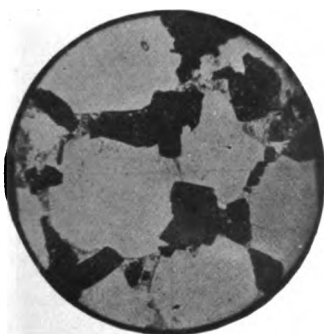


Fig. 5, $\times 67$ diam.

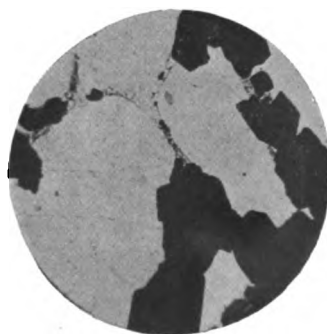


Fig. 6, $\times 67$ diam.

difficulties as regards concentration. In the present case, while there is no obvious source for any unusual quantity of alkaline carbonates, a sufficient supply might, perhaps, be furnished by overlying shales, while the Lorraine formation might be a source of hydrogen sulphide. Iron may have been original in the conglomerate, or derived from overlying rocks. In this connection, Doelter's* production of artificial pyrite by the action of hydrogen sulphide and sodium sulphide on iron carbonate is very suggestive, and may represent some approximation to the conditions involved in the case under consideration.†

If this is true, it is evident that the replacement of quartz by pyrite is caused by common, rather than peculiar, agents, and therefore might be expected to occur with some frequency. As a matter of fact, judging from the literature of ore deposits, it is by no means rare. Lindgren‡ in particular has described several instances within very recent years.

But in all the cases that the writer has thus far found mentioned, the process is connected with some type of mineral vein formation, where, with the hot alkaline solutions and mineralizers, and resultant powerful chemical action, it is not surprising to find even so resistant a mineral as quartz yielding to the agents of alteration. In some of these cases it is, as in the present instance, the quartz of sedimentary rocks that is replaced, but always under the conditions involved in the filling of mineral veins.

These conditions are so unlike those controlling the deposition and subsequent existence of the Oneida conglomerate that the occurrence of pyrite replacing quartz in veins would hardly suggest the probability of the same thing taking place in the conglomerate, and explanations of the former process would, doubtless, require modification before being applied to the latter.

The reagents suggested above are similar to those filling veins, but in the case of the conglomerate their action would, probably, be less intense, owing to lower temperatures and pressures, greater dilution, and the absence of some of the more powerful reagents. Compensation might be afforded by the ready permeability of the formation and the large surface of quartz exposed to attack, while, of course, the time factor

* Allgemeine Chemische Mineralogie, p. 148.

† See a theoretical discussion of the chemistry of pyrite-quartz replacement by C. S. Palmer, Eng. and Min. Jour., lxxix, p. 169.

‡ Metasomatic Processes in Fissure Veins, Trans. Am. Inst. Min. Eng., xxx, p. 615, et seq.

Gold and Silver Veins in Idaho, 20th Ann. Report, U. S. Geol. Survey, iii, p. 219 et seq.

Geological Reconnaissance across the Bitterroot Range, etc. U. S. Geol. Survey, Professional Paper No. 27, pp. 109-110.

would be most important in determining the amount of replacement.

How frequently all the conditions necessary for the replacement of quartz by pyrite are fulfilled in formations similar to the Oneida conglomerate, it is at present impossible to say. Judging from the literature, the matter has never been investigated, which doubtless explains the fact that, so far as the writer can learn, no case similar to the present one has been described.

Whatever sheds light upon the geological relations of so important a mineral as quartz is worth recording, but it is evident that this case of the replacement of quartz by pyrite is of particular significance in its bearing upon ore deposits. In the present instance, the total amount of replacement is comparatively small, but there seems to be no reason why, under more favorable conditions, there should not be a more extensive, or even complete, replacement of quartz by pyrite, and, perhaps, by other sulphides. Although this may be going too far, it is, at least, evident that the phenomena described suggest interesting possibilities.

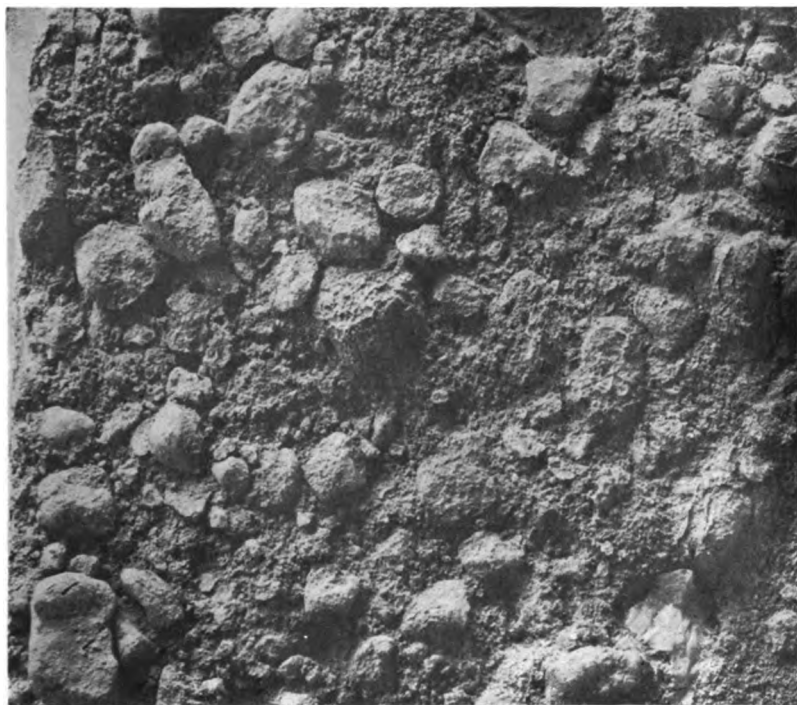
II. *Corrosion of Quartz Pebbles.*

While the replacement of the quartz is clearly a process which was accomplished early in the history of the conglomerate, the same mineral occasionally shows evidence of another change, going on under very different conditions at the present time. Several specimens have been found with projecting pebbles of quartz deeply corroded in a manner indicating the action of some solvent, working, not throughout the mass of the rock, but upon surfaces of bedding planes, or, rarely, of joints and boulders—in other words, where there is exposure to weathering conditions.

The pebbles show most irregular surfaces, often pitted, with sharp jagged projections, and in extreme cases, appear to have lost a considerable fraction of the original mass. As a rule, solution has been most rapid on the tops of the pebbles, and as the cement and sand work out beneath, there is also rapid solution here, the result being the reduction of pebbles to thin plates, with very jagged edges and rough surfaces. Such a marked effect is, however, exceptional, the pebbles more commonly showing a less pronounced change of form, but having the characteristic etched surfaces. The accompanying illustration from a photograph (fig. 1), showing a portion of the surface of a typical specimen (natural size), gives a fairly clear representation of corroded pebbles. While the sand grains are similarly affected, the phenomena are, naturally, much less easily observed.

Unlike the replacement by pyrite, this corrosion of the quartz seems to be a rather exceptional feature of the rock, as but few good examples have been found.

The character of the corroded pebbles is essentially the same as that described by Hayes* and by Fuller,† but in both of these latter cases the pebbles appear to have suffered greater loss, while there is a stronger tendency towards a rapid solu-



tion of the center of the pebble, leaving the margin as a projecting rim. This form is seldom even approximated in the Oneida specimens, but the resemblance to wind-faceted pebbles, noted by Hayes, is sometimes quite pronounced.

Hayes explains the corrosion as due to the action of the azo-humic acids of decaying organic matter, combined with potash derived from forest fires, and regards the process as taking place at the surface.

Fuller concludes that the quartz is dissolved by organic acids supplied by plants buried in the rock when it was deposited,

* Bull. Geol. Soc. Am., viii, pp. 213-226.

† Jour. Geol., x, pp. 815-821.

and holds that the process has taken place at moderate depth beneath the surface.

Long ago, Newberry* regarded the impressions of plant stems upon the quartz pebbles of conglomerate as due to organic acids, and, as quoted by Bolton,† explained in the same way the corrosion of quartz pebbles occurring in carbonaceous clay.

As the present instances of corrosion show no connection with unusual supplies of decomposing organic matter and alkalis, at the surface; and as the conglomerate contains little, if any, original organic matter, none of these explanations seems applicable; but, unfortunately, no satisfactory substitute is forthcoming.

As already stated, the corrosion appears to be a superficial process—a peculiar phase of weathering. To this may be added the striking fact that, thus far, corroded pebbles have been found only in the pyritiferous beds, though carefully sought for in the overlying pure quartz conglomerate.

Thus, corrosion seems to be dependent upon two conditions,—presence of pyrite and weathering,—which suggests the conclusion that the products of the weathering of pyrite act as solvents of quartz. But, so far as the writer is aware, such a conclusion finds no support in the results of laboratory study; and an explanation of the phenomena must await further investigation.

It might be suggested that the corrosion is merely apparent, not real, resulting from the weathering out of pyrite from partly replaced quartz, thus leaving, as would evidently be the case, a rough pitted surface. This simple explanation is not, however, in harmony with the facts. The replacement though greatly modifying the shape of small sand grains, perhaps even completely destroying them in some cases, does not go deep enough to materially change the shape of the larger pebbles, upon which corrosion is conspicuous. So, while mere weathering out of pyrite would give a rough surface, it would not yield the deeply corroded pebbles. Furthermore, a surface left by the removal of pyrite would be marked by depressions corresponding in shape with the pyrite, and, thus, often bounded by small plane faces, which is distinctly not the case with the corroded pebbles.

The rough surface left by the removal of pyrite would, of course, favor solution of the quartz by any agent present, and to this extent, surely, replacement is a factor in the subsequent corrosion.

The Oneida conglomerate, then, presents two types of solu-

* *Geol. of Ohio*, vol. ii, pt. I, p. 111.

† *Ann. N. Y. Acad. Sci.*, i, 1877, pp. 35-36.

tion of quartz, one accompanied by simultaneous replacement by pyrite, and thus metasomatic, the other purely destructive in its nature, and in harmony with the general tendency of weathering. While neither of these processes is of great moment in the history of the formation as a whole, they are interesting in that, as they seem to represent no very unusual conditions, they suggest the possibility that quartz, though unquestionably an exceedingly resistant mineral, may yield rather more readily to the attack of natural solvents than has generally been supposed.

Hamilton College, Clinton, N. Y.

DESCRIPTION OF PLATE II.

- FIGURE 1.—Early stage of replacement, with crystals and irregular masses of pyrite growing between, and into, the quartz grains. Magnified 26 diameters.
- FIGURE 2.—Original margins of quartz grains almost entirely removed, giving jagged contours determined by the forms of pyrite. Magnified 26 diameters.
- FIGURE 3.—Pyrite with unusually irregular forms. Some secondary quartz in upper half of section. Magnified 26 diameters.
- FIGURE 4.—A typical example of replacement in a fine-grained specimen. Nearly all the quartz grains are affected, and show the characteristic contours resulting. It is quite possible that some small grains have entirely disappeared. Magnified 23 diameters.
- FIGURE 5.—Pyrite filling interstitial spaces, and projecting slightly into quartz grains, whose original margins are partly preserved. Some secondary quartz. Magnified 67 diameters.
- FIGURE 6.—Shows very clearly the contrast between original and secondary contours of quartz grains, together with the dependence of the latter upon the forms of pyrite. Some secondary quartz. Magnified 67 diameters.

ART. XXVI.—*Occurrence and Distribution of Celestite-Bearing Rocks* ;* by EDWARD H. KRAUS.

IN July, 1904,† I announced the fact that the mineral celestite occurs quite extensively in a disseminated condition in the dolomitic limestones and shales in the upper portion of the Salina epoch. The celestite-bearing rocks studied at that time were confined to localities in Central New York, especially those near Syracuse. However, in describing the various occurrences, the following statement was made: "I do not doubt, whatever, but that its (celestite) occurrence in the disseminated condition, as shown by the accompanying figures, is just as extensive in the limestones of the Salina elsewhere, as in the vicinity of Syracuse."‡

During the past summer, the Island of Put-in-Bay in Lake Erie was visited. This island has become well known for its interesting caves, among which is the celestite cave, popularly known as "Crystal" or "Strontium" cave. The rocks of the island have been assigned to the Lower Helderberg epoch. Wherever they are exposed along the lake shore they present a more or less porous appearance. There are a goodly number of exposures in various places on the island away from the shore, and even in such places many of the rocks have a structure which is so characteristic of the leached celestite-bearing rocks of Central New York. Numerous specimens were found lying on the surface, which possess cavities with a distinct orthorhombic outline. A very careful search failed to reveal celestite in the interior of such rocks, but the outline of the cavities leaves no doubt, whatever, as to the mineral which had previously occupied them. There is a very striking similarity between these rocks from Put-in-Bay and those from various localities near Syracuse, N. Y. In some instances it would be difficult to tell which specimens were from either place, were it not for the fact that those from Put-in-Bay are for the most part a little lighter in color.

The dissemination of the celestite in the rocks near the surface in the Put-in-Bay region was principally, so far as I have been able to ascertain, in the form of small but well-defined crystals. Celestite has been known to occur for many years at this locality, and also on some of the other islands in the southwestern portion of Lake Erie. Nearly all text-books on mineralogy mention these islands as important localities for

* Read in part before the Philadelphia meeting of the Geological Society of America, December 30, 1904.

† This Journal (4), xviii. 30-39, 1904.

‡ Ibid. (4), xviii, 33, 1904.

the mineral. The celestite, however, which has been studied up to the present time has, in so far as my knowledge goes, all been of secondary origin, in that it has always been found in the cracks, crevices, or cavities in the rocks.

The discovery of the "Strontium" or "Crystal" cave in 1897 showed conclusively that there must have existed somewhere on the island a very large amount of celestite. This cave is perhaps 25 to 30 feet in its extreme dimensions. The form is somewhat irregular and the interior is lined on all sides with well-developed crystals of celestite, some of which are eighteen inches in length. In opening this cave to the public it was necessary to remove some of these crystals in order that suitable passageways might be made. The owner, Mr. Gustave Heinemann, estimates that in so doing no less than 150 tons of celestite were removed. This, however, represents but a small portion of what still remains.

G. F. Wright,* in describing this cave, speaks of it as an immense geode. There is no doubt, whatever, of the secondary origin of the celestite. An examination of the rocks immediately overlying the cave shows that they are of a more or less porous nature.

At the time of my visit to the island in August, 1904, several wells had just been drilled—one on the farm of Louis Schiele on the southeast shore of the lake, and the other at the hotel of August Markley on the road extending southward from the main dock. This last well is not over a quarter of a mile from the "Strontium" cave. Many cores were obtained from these wells. These cores show that the rocks near the surface are very porous. In many instances the cavities are well preserved and reveal the celestite outline. The rocks near the surface show small cavities, but as we go deeper the cavities become much larger, some over an inch in diameter, and the rocks are crossed by numerous cracks. It is in these larger cavities and cracks that excellent crystallizations of celestite are found. These lower cavities, however, do not possess a definite outline, but are more or less irregular. The crystals do not in all cases completely fill the cavity, and in no case does the cavity conform to the celestite outline, as is the case when the mineral occurs disseminated. Figure 1 shows a core from the Schiele well. This core is from the strata near the surface, and shows clearly the porous condition of the rocks. It is not possible for me to give exact figures as to the depth at which this core was obtained, nor can I state how far below the surface celestite is first encountered filling the larger cavities and cracks, for no detailed record of either this or the

* Science, viii, 502, 1898.

Markley well was kept by the driller, Mr. W. T. Hills. This much, however, can be stated, that the cores from the upper strata show that celestite was present in a disseminated condition, and thus the observations on the surface rocks, which were referred to above, are confirmed. Since this is the case, it can be readily seen that these leached rocks are no doubt the source



of the large amounts of celestite which are to be found in some of the lower strata. In this way the very large deposit of celestite, which is to be found in the "Crystal" cave, may be readily explained.

In the paper* already referred to, it was shown that the porous character of celestite-bearing rocks is due to the solution

of the celestite, brought about by the action of the circulating waters, and figures are given showing that if sodium chloride or the chloride of calcium or magnesium be present in the water, the same becomes an excellent solvent for celestite.† Virick‡ says, that one part of celestite is soluble in but 457 parts of water containing 15 per cent. of sodium chloride in solution. Hopper casts were found in several places on the island, so that, without a doubt, conditions for obtaining a suitable solvent for celestite are also present in the Put-in-Bay region as well as in Central New York.

There is, however, another point concerning the solubility of celestite which is worthy of consideration. It is sometimes supposed that, because celestite resists to a very large extent the action of the common acids, it is insoluble or only very slightly soluble in water. A few figures will suffice to show that such a view is erroneous. According to Fresenius,§ one part of the celestite is soluble in 6,895 parts of cold water. F. Kohlrausch and F. Rose|| found the solubility of celestite to be one part in 10,101 parts of water at 15° C. Hollemann¶ also obtained figures almost identical with these,

* This Journal (4), xviii, 36, 1904.

† Since the publication of said paper expressing the belief that the Vermicular limestones of Central New York owe their origin to the removal of celestite—once disseminated throughout them—by percolating waters containing sodium chloride in solution, I have found that in 1869 Bauermann and Foster (Phil. Mag., 38, 1862) had expressed similar ideas concerning the solution of celestite in nature.

‡ Chemisches Centralblatt, 1862, 402; Comey, Dictionary of Chemical Solubilities, 1895, 455.

§ Ann. der Chemie, Bd. lix, 122. || Zeitschr. f. physikal. Chemie, xii, 162-166, 1893.

¶ Zeit. f. Physik. Chemie, xii, 125-139, 1893.

namely, one part in 10,070 parts of water at 16° C. But, inasmuch as the celestite usually occurs disseminated in limestones, let us compare with the above figures concerning the solubility of celestite, some showing the solubility of calcite. Perhaps the most reliable are those of F. Kohlrausch and F. Rose,* namely, that one part of calcite is soluble in 76,924 parts of water at 15° C.

A comparison of these figures for the solubility of calcite with the highest for celestite, which are by the same authorities — Kohlrausch and Rose — shows that celestite is more than seven (7) times as soluble as the limestone rock in which it usually occurs. But in this comparison we have considered the limestone to consist of pure calcium carbonate, which is not the case. They are more or less dolomitic and also contain some silica, thus their solubility would be even less than that indicated for calcite. Of course, waters circulating in nature are never pure, but contain oftentimes, among other compounds in solution, varying amounts of carbon dioxide, which increases to a very considerable extent the solubility of the carbonate rocks. The porous character of these rocks, however, shows conclusively that there is not enough of the carbon dioxide in the percolating waters to cause the limestones to dissolve more readily than the celestite. We can, also, readily see that in order to account for the comparatively easy solubility of celestite over the carbonate rocks, it is not at all necessary to assume the presence of extraordinary amounts of sodium, calcium, or magnesium chlorides in the circulating water.

Thus, by the continued action of water, the celestite disseminated in the strata near the surface, would pass into solution, and as this descends the mineral may, under certain conditions, be again deposited. In this way, the occurrence of celestite in the cracks and cavities is to be explained. The same explanation also applies to the "Crystal" cave. This cave, the ceiling of which is perhaps 15 to 20 feet below the surface, is a large cavity. Into this large cavity or cave, water containing celestite in solution, which was obtained from the overlying strata, flowed, and from it the large crystals crystallized. These large and well-developed crystals indicate that crystallization took place without any serious disturbance or interruption, there being a continual addition of material, i. e., as fast as the celestite was deposited more was brought in by the descending water. Such occurrences of celestite—in the cracks and cavities—are of course of secondary origin.

* Zeit. für. physikal. Chemie, xii, 162-166, 1893.

Another interesting locality, where celestite-bearing rocks may be studied to advantage, is the Woolmitch quarry, located in Exeter township, midway between Maybee and Scofield, Monroe County, Michigan. The geology of this county has been thoroughly studied by Sherzer and a detailed account of the various strata occurring at the Woolmitch quarry is given in his excellent "Geological Report of Monroe County."* Sherzer distinguishes nine different beds at this locality and assigns them to the Monroe series, which is, doubtless, the equivalent of the Salina in New York. For this discussion, however, it is important that the strata near the surface contain a very large amount of celestite disseminated throughout them. In several specimens, taken from what Sherzer calls bed A, crystals of celestite can be easily recognized. That some substance possessing a high specific gravity is present is evidenced by the fact that several determinations of the specific gravity of one of the specimens gave figures as high as 3.45. These rocks are dolomitic and therefore ought to possess a specific gravity of about 2.85 to 2.90. Where they have been protected from the action of water, these rocks are compact, but where they have been exposed for only a short time they assume the porous structure characteristic of celestite-bearing rocks. As in the other localities, referred to above, many of the rocks possess cavities sufficiently well preserved so that the orthorhombic outline may be readily recognized.

In the lower beds many cavities of an irregular nature, varying from a few inches up to a foot or two, are found. In these cavities beautiful crystallizations of celestite are to be noted. In some instances, the crystals are from four to six inches in length. Associated with the celestite there often-times occurs a considerable quantity of native sulphur and also, now and then, small amounts of calcite. The celestite is, however, by far the predominant mineral.

At this locality the changes, which are now actually taking place, may be followed very easily and furnish the best of evidence in proof of the solution of celestite in the strata near the surface and deposition in the lower and cavernous beds. The well-developed crystals of celestite, — in some cases four to six inches in length — which are found in these larger cavities in the lower strata, are therefore the result of transportation by means of solution from the higher to the lower layers of rock, and not, as Sherzer† suggests, due to the interaction in these cavities of a solution of gypsum with another containing a soluble salt of strontium. That the celestite has actually gone into solution is shown, first, by the pecu-

* Part I, volume viii of the Geological Survey of Michigan, 1900.

† Geological Report of Monroe County, 1900, 208.

liar porous structure of the leached rocks, and secondly, that many celestite veins can be found crossing the various strata, usually in a vertical direction.

As already said, many of these leached rocks possess cavities with outlines well enough preserved so that no doubt exists as to what the mineral was which originally occupied them. The best of such cavities, which have been studied thus far, are usually quite small. In many instances cavities are encountered which cannot be readily recognized as having been caused by the solution of celestite. Some of these appear as though the point of a knife had been thrust into the rock material while in the process of hardening, and on this account the term "gashed" dolomites has been used by Lane, Sherzer and others.

Sherzer* refers especially to such an occurrence at the Ida quarries, likewise in Monroe County, but adds that such phenomena can be seen throughout the whole Monroe series. In fact, this peculiar structure has been observed in many places in Michigan. Winchell in his report of 1860 calls it an "acicular" structure. He thought that gypsum was the original occupant of the cavities. Later on, Rominger also used the term acicular but made no definite statement as to what mineral had occupied the cavities. Lane,† however, mentioned calcite as possibly having been the original occupant. One of the difficulties in recognizing the original occupant of such "gashed" cavities has been due to the fact that the orthorhombic outline is not always definitely preserved. Sherzer aptly describes them as follows: "The rock looks as though, when it was only very slightly plastic, it had been jabbed in every direction with a thin-bladed, doubled-edged knife point. The gashes are always open, intersect one another irregularly and vary greatly in size, some being two-thirds of an inch long, while others can scarcely be seen without the magnifier. The cross-section of each gash shows that it is thickest at the center and that it slopes gradually and symmetrically to a very thin edge." Such an outline can be readily referred to celestite, when we bear in mind that crystals of this mineral are often found which have a tabular habitus, that is, the basal pinacoid is predominant. Cross-sections through such tabular crystals would conform very closely indeed to Sherzer's description above of the so-called "gashes."

Another reason why the original occupant of these cavities evaded detection lies in the fact, that celestite had not up to the present time ever been noted as occurring in these rocks in a disseminated condition, that is, in a condition of primary origin. Therefore, with these facts before us, first, that celes-

* Geological Report of Monroe County, 1900, 85.

† Ibid., foot-note, p. 86.

tite does occur very extensively in the dolomitic limestones of the Monroe series in a disseminated condition, and secondly, that when the mineral is thus disseminated it is usually in the form of well-defined crystals of either a prismatic or tabular habitus, and thirdly, that since celestite is, as previously shown, quite readily removed by the continued action of water, *we have every reason to believe that the phenomenon referred to as "gashing" or "acicular structure" has been produced by the mineral celestite.*

2



As previously noted, the celestite in these three localities occurs in a so-called disseminated condition, that is, the mineral is distributed throughout the rock. Figure 2 represents a specimen from Jamesville, N. Y. The rock is a drab dolomitic

3

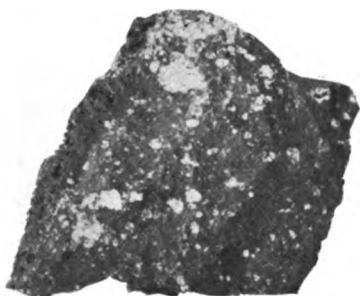
4



limestone. The cavities, as can be readily seen, are all sharp and angular, and range from one-quarter of an inch up to an inch or more in size. In the interior of these specimens a considerable

amount of celestite is still present. Figures 3 and 4 represent a specimen (two views) from Split Rock, a short distance west of Syracuse, N. Y. In this specimen a very large percentage of the rock was celestite, as is indicated by the large number of cavities. In the interior the mineral is still to be seen. A comparison of these figures (3 and 4) with figure 1 shows that a very close similarity exists between the two occurrences. Figure 5 shows another specimen from Jamesville, N. Y.,

5



where the celestite appears disseminated in small irregular spots.*

A study of these and other specimens shows first, that the celestite is or was actually distributed throughout the rock, or in other words, imbedded in the rock; second, that the cavities, which remain after the mineral has been removed by solution, conform for the most part to the original outline of the celestite; and thirdly, that many of these cavities are very sharply defined, being bounded by smooth surfaces. Therefore, the conclusion is forced upon one that *the celestite was no doubt deposited simultaneously with the rock material, and also that as the crystals of celestite formed, the soft rock material yielded and surrounded them on all sides. Such occurrences may, hence, be considered of primary origin.*

Further investigations as to the crystallography of the celestite in these localities, the amounts of the mineral actually present in the rocks and the origin of the sulphur which is associated with the celestite, especially at the Woolmuth quarry, are in progress in this laboratory and will be reported upon as soon as feasible.

I am indebted to Dr. G. P. Burns for the photographs which accompany this paper.

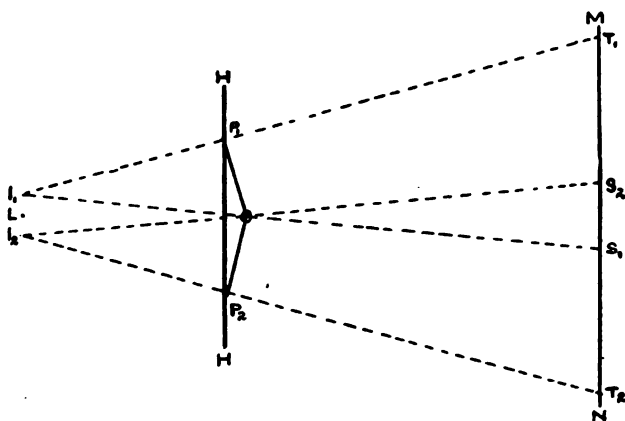
Mineralogical Laboratory, University of Michigan,
Ann Arbor, Mich., January, 1905.

* Compare figs. 1, 3, 4, 5 with those shown in a previous paper "The Occurrence of Celestite near Syracuse, N. Y., etc.," this Journal, lviii, 31, 33, 34, 1904; fig. 2 is repeated from that paper.

ART. XXVII.—*A Note on Interference with the Bi-Prism ;*
by WILLIAM MCCLELLAN.

IN most descriptions of interference with the bi-prism the trouble which diffraction is likely to cause receives scant attention. It is true, reference is usually made to the fringes that are commonly found to border the field, but not as if they could seriously detract from the result. Some time ago, on setting up a prism on an optical bench, a colored center was obtained, and apparently no amount of adjusting would make it appear white. This, of course, proved the presence of something other than interference, that is, diffraction. The matter was

1



studied a little, and an explanation found which is quite simple. It is obvious that the condition of the field as obtained from a given prism depends upon the relation of the distances between the prism, screen and light. The fact is well known to many experimenters, but no detailed note has ever been observed by the writer, in any text. This is probably due to the fact that the bi-prism is a lecture-room piece rather than one for the laboratory. The following explanation is suggested.

Let L (fig. 1) be a source of light, and I_1, I_2 its two images formed by the bi-prism P_1, P_2 . MN is a screen. We may treat the diagram as if I_1, I_2 were separate sources, as they might be if we could arrange constant phase relations. Light coming from I_1 will light the screen from S_1 to T_1 if we consider the prism set in an opaque holder HH . Similarly, light

from I_1 will illuminate S_1T_1 . The space S_1S_2 is lit by both sources and is therefore the interference field. It is necessary to notice however that as no light from I_1 can fall below S_1 , the prism face OP_1 can be looked upon as an opaque screen for I_1 . Consequently we find diffraction bands extending from S_1 into S_1S_2 . In like manner fringes will extend inwards from S_2 . Now it is easily seen that if the two sets of diffraction fringes should extend so far into S_1S_2 as to meet, there would be no clear field in which pure interference could be seen. The two kinds of bands would be superimposed, and neither would be seen as they are. This, of course, is precisely what does happen if conditions are not arranged to prevent it. It is easy to find what these conditions are.

Let the distance from light to prism be a , and that from prism to screen be b . Let the angle OP_1P_2 be e . Then if d be the angle I_1OL and u the index of refraction, $d = (u-1)e$ which is half the angular space S_1OS_2 . The half interference field on the screen is then $b(u-1)e$.

Now regarding OP_1 as a screen for the source I_1 , and x as the distance of the $2n$ th diffraction band from the geometrical shadow,

$$x = \sqrt{\frac{b(a+b)}{a} \cdot 2n\lambda}$$

it is evident that if we are to have an open field for pure interference, this distance x must be less than the half interference field, that is,

$$\sqrt{\frac{b(a+b)}{a} \cdot 2n\lambda} < b(u-1)e$$

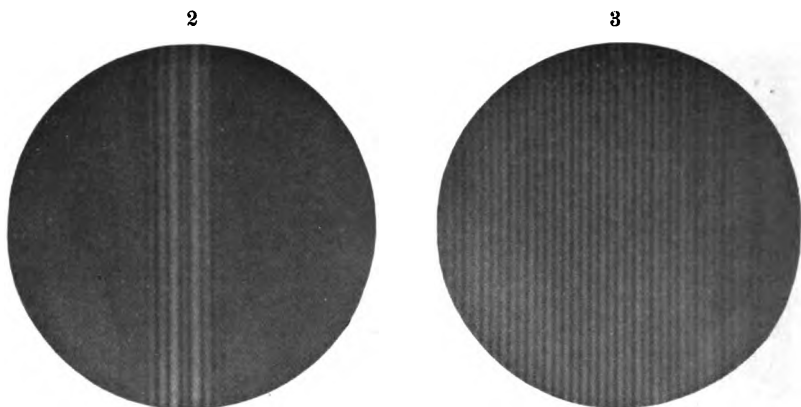
or reducing

$$\frac{1}{a} + \frac{1}{b} < \frac{(u-1)^2 e^2}{2n\lambda}$$

for any given prism, u and e can be measured. n is a constant for all prisms, and is simply the number of that pair of bands for which the ratio of intensities is so close to unity as not to permit of separation by the eye. This value can be calculated or observed. Either method shows that six is a fair value for n . λ , of course, depends upon the light used. It should be noticed that while a prism with a large angle e , according to the formula, will give a clear space more easily, the interference lines will be narrower the larger the angle. This is shown by the expression for the width of interference lines, $\frac{\lambda}{2(u-1)e}$. For this reason the prisms supplied for this purpose usually have

small angles, which give wider lines but a very narrow clear space.

Figures 2 and 3 will illustrate the above discussion. They are reproduced from photographs taken on the optical bench, using the eye-piece as an objective. Figure 2 shows the two



sets of lines superimposed; the center band could be made any color desired, by changing the distances a and b . Figure 3 shows a half field with complete separation. On the left the two sets of lines can be seen superimposed, while on the right the interference lines alone are seen. Another photograph, not reproduced, shows a whole field with very complete separation, the central portion covered with very fine interference bands.

Randal Morgan Laboratory,
University of Pennsylvania.

ART. XXVIII.—*The Doughty Springs, a Group of Radium-bearing Springs, Delta County, Colorado;** by WILLIAM P. HEADDEN.

THE group of springs, known as the Doughty Springs, is situated on the right bank of the North Fork of the Gunnison River in Delta County, Colorado, about four and a half miles from the town of Hotchkiss. They are almost wholly unknown to the public, and are but little more than objects of curiosity to the people of the neighborhood. My attention was called to them about two years ago by H. E. Mathews, in whose company I first visited them.

The odor of hydrogen sulphide is noticeable for some distance from the springs, but the extensive sinter bed is a more striking feature, especially to persons more familiar with mineral springs in general.

A superficial examination of the surroundings, particularly of the face of the cliff, which rises immediately behind the springs to a height of 130 feet, suggests even more strongly than the sinter bed, that these springs or waters from some other source are heavily charged with salts and are now acting upon the sandstones and shales to a very readily observed extent.

The sinter bed is 400 feet long by 147 feet wide, measured at the widest part, with an average width of about 115 feet. The thickness of the bed where exposed along the river is about 20 feet, but increases a little as we approach the springs, showing that a general deposition is now taking place. There is but one instance of cone building and the little streams which flow across the surface of the bed have not formed elevated margins to mark their course.

The formation of the cone about this one spring is due to the fact that it is surrounded by a rank-growing grass, whose leaves and stems falling about it serve to catch and hold the sinter-forming material until cemented together, forming quite a compact sinter.

The sinter bed extends from the springs, which are situated near the base of the cliff, to the river, where it forms an almost perpendicular face. The river has encroached upon the bed by undermining and causing the overhanging sinter to

* An abstract of a paper read before the Colorado Scientific Society, Jan. 13, 1905. This paper was presented by permission of the President of the College.

break off; such broken-off pieces, 20 feet in width, are still remaining.

The cliff rises perpendicularly to a height of 130 feet immediately back of the springs, but is higher at points both above and below them; in structure it presents an alternation of sandstones and shales with a stratum of conglomerate near the top. This series probably belongs to the upper portion of the Dakota.

While the flow from the individual springs is not notably large, the aggregate flow of the group is very considerable. The large number of small springs in the group is probably due to impeded outflow, whereby the waters are forced to find various passages for their escape. According to my information, one spring issues in the bed of the river. All of the springs emit gases in moderate quantities, but the emission is continuous. In addition to the flow of the springs proper, small streams are issuing from the face of the sinter bed at very many places, in fact, almost throughout its entire length. Assuming this water to come from the springs, their actual discharge must be quite large, but it is not certain that this assumption is wholly correct. I have no doubt but that waters coming from the cliff, including some surface waters, do find their way into the springs under the present conditions, but the amount of this water is wholly insignificant, and without influence upon the flow of the springs. While I do not think that there is any significant quantity of surface water finding its way into these springs, it does seem probable that some of the waters represent mixtures of different springs. It is clearly evident that there are three distinct types of water represented by the analyses which I shall give. There is, however, a number of springs, how many I do not know, whose waters are intermediate in character between two of these types.

The gases emitted by these springs consist largely of carbon dioxide and hydrogen sulphide, but I have not yet submitted them to an examination. I am of the opinion that they will prove to be as interesting as the waters themselves or their deposits.

These springs are, so far as the writer is aware, wholly unknown to the general public, and have no individual names, but are spoken of collectively as the Doughty Springs. It is true that one of them is called the Black Spring, because the water as it lies in a basin adjoining the spring proper appears black; another is called the Bath Tub, because of its size and convenient depth for bathing; also, because there are good reasons to believe that the Indians used it for this purpose, for according to Mr. Doughty, the mud which had gradually

collected in the bottom of the spring was found to contain an abundance of beads and Indian trinkets lost by the bathers. The Indians attributed great medicinal virtues to this and to the other springs also. A third spring is called the Drinking Spring, because the water of this spring is preferred to that of any of the others for this purpose. I do not know the reason for this choice, but those who are accustomed to it drink it very freely. This preference is probably another instance in which the general judgment has arrived at a correct scientific conclusion based upon some effect which it either cannot or never troubles itself to formulate. It will appear later that this is the most remarkable spring in the group and constitutes one of the three types to which I have alluded.

There are but three springs in the group whose waters are clear; they are the Black Spring, the Drinking Spring, and a smaller one designated the Alum Spring. The other springs show a pronounced milkiness. The presence of hydrogen sulphide would, according to general observation, account for this, especially in the case of springs having a small flow and presenting a large surface to the air, such as the Bath Tub, whose diameters are 19 and 27 feet respectively. Some of the smaller springs, however, having a comparatively large flow of water and gases—conditions tending to reduce this degree of milkiness, are more turbid than the Bath Tub, and suggest that the presence of hydrogen sulphide is not the cause of the milkiness, which is really the case. I shall subsequently show that it is almost wholly due to the separation of baric sulphate and not to sulphur set free by the decomposition of hydrogen sulphide.

The Black Spring is clear, but it is forming little or no deposit from its waters. While there is some deposit formed on the shale through which the spring issues, this deposit is almost pure sulphur and undoubtedly owes its origin to the oxidation of the sulphide. This spring has a basin contiguous to it, but the deposit forming in this is black (from which fact the spring obtains its name), and consists essentially of ferrous sulphide with manganous sulphide and a trace of zinc sulphide. The Alum Spring is clear, but its deposits are of an entirely different character from the sinter formed by the other springs. The Drinking Spring is perfectly clear and sparkling, and is actively depositing sinter outside of the spring. This sinter is practically pure baric sulphate.

The milkiness of the other springs is due to the separation of baric sulphate in an extremely fine state of division: this separation probably takes place before the waters actually come to the point of their discharge. The cause of the sep-

aration is probably to be found in the mingling of waters from different springs quite near to the surface. We have the Drinking Spring at one end and the Black Spring at the other, both clear, while the intermediate ones are turbid. The water of the Black Spring is different from that of the Drinking Spring, and a mixture of these waters would bring about the precipitation of baric sulphate. The precipitated baric sulphate is in an extremely fine state of division, and the flow of water and gas is sufficient to keep it in suspension and produce the milky appearance of the water.

The considerations which lead me to this conclusion are the following:

The Drinking Spring is perfectly clear and contains a very marked quantity of barium in solution. This spring is depositing a baritic sinter outside of the spring.

The other springs are turbid or milky. Their waters contain only a very minute trace of barium after the milkiness has disappeared. A baritic sinter is forming in and about these springs.

A spring designated as the Birds Nest is building a cone about its vent consisting very largely of baric sulphate precipitated within the spring and washed up and out by the out-flowing gases and water. The water contains only a minute trace of barium.

A small amount of deposit was obtained from five gallons of water dipped from the Bath Tub; this deposit contained in whole numbers 25 per cent of baric sulphate and only a minute quantity of sulphur. The fine impalpable mud from the bottom of the Bath Tub contained almost 40 per cent of baric sulphate.

The foregoing facts convince me that the explanation offered to account for the milkiness of these springs is correct. It further seems to me to follow that water similar to that of the Drinking Spring is the source of the barium, while the precipitant is probably a water of the type of the Black Spring. If the precipitation takes place very near to the surface, it is possible that water of surface origin may participate in the precipitation.

I cannot give the number of springs in this group. The strip extending from the Drinking Spring to the Black Spring, a distance of 150 feet or more, is an area of general discharge with a number of well defined springs.

The waters of these springs are, at first, not very acceptable to the palate and the average person would have to acquire a taste for them. The characteristic in their taste is not due to the hydrogen sulphide. I do not know to what one can liken their taste, especially that of the Drinking Spring, which sug-

gests to me simultaneously the taste of hydrogen sulphide and that of hydrogen peroxide.

All the springs of this group with the exception of the Alum Spring furnish drinkable waters, but the preferred ones are the Drinking Spring and the Black Spring. The water of the Alum Spring is so astringent that its character becomes apparent to one immediately upon tasting it.

Black Spring.

This is the most westerly spring of the group of any size; its diameters are 30 and 48 inches respectively. The flow is not very strong and is accompanied by a continuous but moderate discharge of gas. The water is clear and has a temperature of 17.5° C.

The presence of the following substances is not noted in the analyses: sulphides other than hydrogen sulphide; titanio, phosphoric, and dithionio acids. I could not examine the waters until the samples had become so old that a determination of the sulphides and the dithionio acid would have been of but little or no value.

I determined the dithionio acid in the water of the Black Spring while the sample was comparatively fresh; its value, however, is not great, for the sample was already several days old. Phosphoric acid is present in minute traces; titanio acid also, but the reactions for the latter were very faint, and may have been erroneously interpreted. I did not detect either caesium or rubidium in the amounts of water used, from three to six liters.

ANALYSIS OF BLACK SPRING.

Calculation of Cations.

	Per liter.		Monivalent ions.
Na.....	1.1978	0.051964	0.051964
K.....	0.0589	0.001504	0.001504
Li.....	0.0016	0.000224	0.000224
NH ₄	0.0013	0.000074	0.000074
Ca.....	0.1261	0.003152	0.006304
Ba.....	None		
Sr.....	0.0035	0.000039	0.000079
Mg.....	0.0609	0.002500	0.005000
Fe.....	0.0012	0.000021	0.000042
Al.....	0.0046	0.000168	0.000504
Mn.....	0.0040	0.000072	0.000144
Zn.....	Trace		
Sum.....	1.4599		0.065839

Calculation of Anions.

	Per liter.		Monivalent ions.
Cl	0·8157	0·023009	0·023009
Br	0·0147	0·000184	0·000184
I	Trace		
SO ₄	0·2731	0·002843	0·005686
SiO ₃	0·0235	0·000308	0·000616
BO ₂	0·0001	0·000003	0·000003
S ₂ O ₃	0·0108	0·000096	0·000182
Sum	1·1397		0·029680
Sum of cations		0·065839	
Sum of anions		0·029680	
Excess cations		0·036159	

The excess of cations, 0·036159, equals CO₂ ions expressed as monivalent ions or 0·018079 bivalent ions corresponding to 1·08474 grams CO₂, equal to 0·794438 gram CO₂, combined as neutral carbonates.

Total CO ₂ found was	2·5660
CO ₂ combined as neutral carbonates	0·7944
	1·7716
CO ₂ combined as bicarbonates	0·7944
CO ₂ wholly free per liter	0·9772

The CO₂ wholly free corresponds to 496·84^{cc} per liter at 0° C. and 760^{mm} pressure.

Hydrogen sulphide considered as wholly free equals 0·0492 gram or 32·12^{cc} per liter. Specific gravity at 16° 1·00400. Total solids 3·6825 grams per liter.

The Drinking Spring.

The water of this spring is by far the most interesting one of all the group: it is clear and limpid with a decided odor of hydrogen sulphide. The discharge of gas is moderate but constant. There are smaller springs of the same character in its immediate vicinity. The spring is nearly circular with a diameter of 12 to 14 inches.

ANALYSES OF DRINKING SPRING.

Calculation of Cations.

	Per liter.		Monivalent ions.
Na	1.0571	0.045863	0.045863
K	0.0617	0.001576	0.001576
Li	0.0031	0.000446	0.000446
NH ₄	0.0012	0.000068	0.000068
Ca	0.1057	0.002636	0.005272
Ba	0.0132	0.000096	0.000192
Sr	0.0066	0.000075	0.000150
Mg	0.0394	0.001615	0.003230
Fe	0.0007	0.000013	0.000026
Al	0.0005	0.000018	0.000054
Mn	0.0016	0.000030	0.000060
Zn	Trace		
Sum	1.2908		0.056937

Calculation of Anions.

Cl	0.7005	0.019762	0.019762
Br	0.0052	0.000065	0.000065
I	Trace		
SO ₄	0.6252	0.006511	0.013022
SiO ₃	0.0266	0.000348	0.000696
BO ₃	0.0075	0.000174	0.000174
Sum	1.3652		0.033719

Sum of cations..... 0.056937

Sum of anions 0.033719

Excess of cations..... 0.023218

The excess of cations, 0.023218, equals CO₃ ions expressed as monivalent ions or 0.011609 bivalent ions corresponding to 0.69654 gram CO₃, equal to 0.5108 gram CO₃, combined as neutral carbonates.

The total CO₃ found was..... 3.0800 grms.

Less CO₃ combined as neutral carbonates . 0.5108

2.5692

Less CO₃ combined as bicarbonates 0.5108

CO₃ wholly free per liter..... 2.0584

The CO₃ wholly free, 2.0584, corresponds to 1047.53^{cc} at 0° C. and 760^{mm} pressure.

The hydroden sulphide considered as wholly free equals 0.0471 gram per liter equal to 30.88° at 0° C. and 760^{mm} pressure. The specific gravity at 15.5° was 1.00377. The total solids = 3.3525 grams per liter.

Deposits of various salts occur rather abundantly on the face of the cliff; these are for the most part easily soluble salts, but some of them are more difficultly soluble. Gypsum occurs occasionally but is not common.

These salts might owe their formation to surface waters finding their way through the strata to the face of the cliff. The dip and character of the strata are such that if this be the case the waters must come from considerable distances. On the other hand, the waters saturating the strata might be spring waters, in which case the incrustations ought to resemble the deposits from the spring waters. These considerations motivated me to examine a few of these deposits and led to some very interesting observations.

An incrustation occurring on the face of the sandstone stratum 150 to 200 feet east of the Drinking Spring and five feet or more above the upper margin of the talus soil was found to contain 2.50 per cent of sulphur with calcium, barium, potassium, lithium and sodium. Though this sample was collected 150 feet or more from the nearest observed spring and from the face of a compact sandstone stratum under conditions precluding accidental deposition, its qualitative composition is strongly suggestive of the matter held in solution by the water of the Drinking Spring. The appearance of this incrustation on the face of the sandstone fairly raises the question of the source of these waters, i. e. are they waters finding their way along and through the strata, or are they forced into the strata from below? I am inclined to the view that they come from greater depths, but the springs themselves do not indicate a high pressure.

Another sample collected 50 feet or more up on the face of the cliff proved to be the mineral mirabilite. It was well crystallized and was not associated with other minerals. It is not at all rare to find this mineral deposited from some of our alkali waters in crystals five or six inches long, but in this case it probably came from the stratum of shale.

Another deposit collected from the rocks at the base of the cliff immediately back of the Black Spring had an entirely different composition. It was this that led me to examine the water designated as the Alum Spring.

This deposit occurred associated with well defined crystals of gypsum; it was white, pasty, and astringent to the taste. When a coil of clean iron wire was brought into its aqueous solution, hydrogen was set free quite rapidly. A solution of

aluminic sulphate treated in this manner will liberate hydrogen, but not nearly so rapidly as this solution. A comparative test showed the evolution of hydrogen from a solution of aluminic sulphate to be less than one fifth as rapid. This deposit placed in contact with cotton cloth or paper destroys it.

The analysis of this sample presented some difficulties and the footing of the analysis is over one hundred. The sample was dried for three days at the temperature of the room; its weight was nearly constant during the last day.

The analytical results were as follows:

	Per cent.
Loss on drying in water oven for ten hours ..	29.61
Loss on drying in air-bath at 147° for two hours	15.35
Insoluble in water	2.72
SO ₃	32.89
Fe ₂ O ₃	1.16
FeO	Trace
Al ₂ O ₃	6.71
CaO	0.69
MgO	3.33
Na ₂ O	4.68
K ₂ O	0.32
Li ₂ O	Heavy trace
Ignition with addition of lead oxide	4.45
	<hr/>
	101.91

The reactions of this material are those of an alum, and the composition is between that of mendozite and pickeringite. The material did not seem to me to justify a repetition of the analysis, especially as I intended to visit the locality again to determine, if possible, whether there is a spring at this point whose waters would account for the formation of such a deposit as this. On my next visit I found that heavy rains following periods of freezing and thawing had caused large quantities of material to come down from the cliff above, and the point where I had obtained this sample was covered deeply under mud and rocks. We succeeded in digging two holes from which we obtained samples of water: one of them was clear but the other was turbid, due to the presence of a white precipitate. Neither of these samples was satisfactory, but I could not obtain better ones. The following analysis serves thoroughly well to show the character of the water collected, though it is not so complete as some of the others. The sample was not from a definitely located spring, and the analysis given is of as much value as a fuller one would be.

ANALYSIS OF ALUM SPRING.

<i>Cations.</i>			
	Per liter.		Monivalent ions.
Na.....	0.4561	0.019786	0.019786
K.....	0.0216	0.000551	0.000551
Ca.....	0.4089	0.010198	0.020396
Mg.....	0.1888	0.007750	0.015500
Fe.....	0.1485	0.001860	0.003720
Al.....	0.3036	0.011203	0.033609
Sum.....	1.5275		0.093562
<i>Anions.</i>			
Cl.....	0.2790	0.007869	0.007869
SO ₄	3.5275	0.036608	0.073216
SiO ₃	0.0745	0.000975	0.001950
	3.9810		0.083035
Sum of cations.....		0.093562	
Sum of anions.....		0.083035	
Excess of cations.....		0.010527	

The excess of cations, 0.010527, expressed as monivalent ions correspond to 0.005264 bivalent CO₃ ions or 0.2316 gram CO₃ per liter as neutral carbonates. Specific gravity at 15.5° C. 1.00546. Total solids 5.7401.

If the calcium were removed from this water in the form of gypsum it would give rise to just such a mixture as we actually found.

The sample which remained milky was not analyzed, but it was thoroughly shaken and a portion of it filtered, and the white precipitate examined; it consisted principally of aluminic hydrate.

As the point at which I had formerly found the white, pasty mass, an analysis of which has already been given, was buried under a mass of débris, I of course failed to obtain more of it, but I found at this place masses of the mineral alunogen. This mineral occurs abundantly at the base of the conglomerate previously mentioned, and the specimens found at this time may have come from this source.

The most interesting feature of these springs is the sinter bed which they have formed, of which there is probably more than a million cubic feet remaining at this time. An analysis of a general sample taken from the face next to the river gave the following results:

ANALYSIS OF GENERAL SAMPLE OF SINTER FROM FACE OF BED NEXT TO THE RIVER.

	Per cent.
Sand and SiO ₂	0.51
Organic matter	2.29
CO ₂	39.39
Cl.....	Trace
SO ₂	Trace
CaO	48.84
SrO	1.16
BaO in HCl solution.....	Trace
MgO	1.37
Fe ₂ O ₃ }	0.20
Al ₂ O ₃ }	
MnO	0.62
Na ₂ O	Trace
Li ₂ O	Trace
BaSO ₄	5.42
	<hr/> 99.80

Other general samples from different parts of the bed were tested and baric sulphate found to be present in all of them, the percentage ranging from 3.25 to nearly 10.0 per cent. As the sinter was richer in baric sulphate as we approached the end of the bed where the Drinking Spring is located, I took two samples, one from near the spring and the other at the spring, and analyzed them with the following results:

ANALYSIS OF SINTER TAKEN 8-10 FEET FROM THE DRINKING SPRING.

	Per cent.
Organic matter with a little free sulphur	3.43
CaCO ₃	26.46
BaSO ₄	66.98
Fe, Mn, Na, K and Li not determined	[3.13]
	<hr/> 100.00

ANALYSIS OF SINTER TAKEN WITHIN 2½ FEET OF THE RIM OF THE DRINKING SPRING.

	Per cent.
Organic matter with a little sulphur	3.11
CaCO ₃	1.84
BaSO ₄	94.62
Mg, K, Na and Li	Traces
	<hr/> 99.57

The spring designated the Bird's Nest is building a cone of this baritic sinter: it has the following composition:

	Per cent.
Organic matter, etc.	7·82
CaCO ₃	43·39
BaSO ₄	48·79
Sr, K, Na and Li	Traces
	<hr/> 100·00

The Bath Tub furnishes the finest samples of this baritic sinter. The spring is lined with a pure cellular barite. The sample which I used as a source of this barite for analysis was from the Bath Tub, but was chosen to represent an average sample of this sinter as it occurs near the springs.

ANALYSES OF SINTER FROM THE BATH TUB.

	Per cent.
Soluble in acetic acid	15·46
Soluble in HCl conc., not soluble in acetic ...	1·33
Insoluble, BaSO ₄	83·21
	<hr/> 100·00

Analysis of the insoluble portion.

SiO ₂	3·25
SO ₂	32·25
Al ₂ O ₃ }	0·80
Fe ₂ O ₃ }	
BaO	63·00
CaO	0·30
SrO	0·45
MgO	Trace
K ₂ O	0·17
Na ₂ O with heavy trace of lithia	0·29
	<hr/> 100·51

The barium determination is too high; the chromate should have been reprecipitated a second time.

The examination of these samples of sinter show that the bed passes from a calcareous sinter carrying a few per cent of baric sulphate to a pure barite sinter at some of the springs. This I believe to be a unique fact. Frequent mention is made of the occurrence of barium in mineral springs, mostly in traces, but I have found mention of only one water which deposited baric sulphate, a mine water in England.

I have stated that I regret not having yet examined the gases given off by these springs. I am fully convinced that they contain helium, for these waters contain, as I shall now show, comparatively abundant quantities of radium.

The close relationship between barium and radium and the well-known fact that barium possesses the property of carrying down other substances with it when precipitated from its solution and radium in a very high degree, made it almost certain that I would find this sinter to contain radium provided any at all were present in the springs.

I was forced to depend upon its action on the photographic plate in testing for it. The action of the sinter as it was broken from the bed, always from points near or at the springs, was of course weak compared with the action of Gilpin County pitchblende, but it was always present and could be seen during the development of the plate even if it were invisible after fixing and drying,

In one experiment made to test the action of the sinter in comparison with that of pitchblende the plate was covered with two thicknesses of black paper and a piece of pasteboard and the exposures made for five days; the radiograph obtained with the pitchblende was distinct but not sharp; the plate exposed to the action of the sinter showed the stencil used while it was being developed, but not when fixed and dried.

I next undertook the preparation of radiferous barium chloride. For this purpose I fluxed 13 pounds of sinter with sodic carbonate, washed, dissolved in HCl , removed silica and iron by usual methods and crystallized out the baric chloride; the yield of crude BaCl_2 was eight pounds. This was subjected to fractional crystallization at last from HCl solution. When the mass of BaCl_2 amounted to rather less than 2 ozs. it was allowed to stand for 15 days to regain its β and γ rays and then tested. This preparation gave an impression upon the plate after an exposure of $2\frac{1}{2}$ days comparable to that made in five days by pitchblende. The distance between the film and the salt was from 0.25 to 0.5 centimeters and the plate was covered with two thicknesses of black paper. I did not deem it necessary to carry this work further for the purposes of this immediate work.

So far as I am able to discover, this group of springs is unique in that it is depositing a baritic sinter, and also in the presence of radium in comparatively large quantities.

State Agricultural College,
Fort Collins, Colorado.

ART. XXIX.—*The Error of Collimation in the Human Eye*;
by C. S. HASTINGS.

[The references H in the following pages are to the *Handbuch der Physiologischen Optik* von H. von Helmholtz. Zweite Auflage, 1896.]

ONE of the most curious imperfections of the human eye, of the many discovered or investigated by Helmholtz, is that of an unfailing inclination of the line of sight to the axis of symmetry of the cornea (H. p. 17), or, what appears to be essentially the same thing, to the geometrical axis of symmetry of the whole eye (H. pp. 108, 109). There is, it is true, no reason for surprise that such an error should exist, since, if we suppose, as we are obliged to do, that the present structure of the eye is the result of a long process of evolution, we ought to expect the survival of imperfections which, too minute to impair the effectiveness of the eye as a sense organ, would therefore be too minute to serve as incentives to farther development. Such surviving imperfections would be called errors when we regard the eye as an optical instrument; and Helmholtz has shown that no error which can be named by the optician is absent from the eye. On the other hand, this eminent investigator has shown that these errors are always so small, in a normally formed eye, as not to impair the precision or visual perceptions with the eye of its present size. This point may be emphasized by the following consideration. If it were required to remodel the eye so as to double its present power, it can easily be shown that this would necessitate an increase of volume to fifteen or twenty times its present value. In view of the enormous difficulties to be met in nourishing and protecting such an organ with a retention of its transparency, we may well conclude that the balance between physiological cost and utility has already been attained, in short, that the closest approach to practical perfection has been reached long ago, even in the protracted history of evolution.

The particular error, however, which is the subject of our consideration and which would be known to opticians as an error of collimation, is distinguished from nearly all others in two peculiarities; first, it is the easiest of all errors in an ordinary optical instrument to eliminate, and second, it is systematic, i. e. it is of such a character that the axis of vision always lies on the nasal side of the geometrical axis outside of the eye. It is this systematic character of the error which gives it its particular interest and for which we feel ourselves prompted to seek a reason.

The first step in an investigation with this end in view is to find the average value of the error. Helmholtz himself (H. p.

19) measured this angle for three eyes only, but Dr. Uhthoff (H. p. 22) adds four, and H. Knapp (H. p. 109) gives data from which we may deduce, with considerable confidence, four more. We thus have eleven cases of which the average value of the angle (α) is $5^{\circ}36$. This is an insufficient number to serve as the basis of any important conclusions, especially in view of their great irregularity of values; it seemed desirable, therefore, to collect a larger number of instances. In this work Professor F. E. Beach kindly aided me with great skill, and to him is due more than half of all the measurements of which the results follow.

The method employed was quite like that devised by Helmholtz (H. pp. 15–19), except that we used a filar micrometer instead of an ophthalmometer. Both methods were tried, but, notwithstanding the obvious advantages of the double image instrument, the former was found quite as accurate and materially more rapid. With this arrangement we found for 52 eyes the following results:

I. There was no case of reversal in sign of α , that is, the axis of vision, extended outwards, always lies on the nasal side of the axis of symmetry of the cornea.

II. The value of α varies greatly. The smallest value which we found was $1^{\circ}25$ and the largest $7^{\circ}76$. There was no evidence of a systematic difference in the numerical values of the angle for the right and the left eye.

III. The mean value for the 52 eyes examined was $3^{\circ}98$.

The mean value is much less than that of the German measures; this may be owing to racial differences—it is well known that the average separation of the eyes is less for Americans than for Germans—or it may be owing simply to the small number of cases in the earlier group. However this may be, it seems that the best attainable value at present is the weighted mean of these two averages, namely:

$$\alpha = 4^{\circ}2$$

We shall assume in our further studies, therefore, that a line drawn from the second nodal point in the normal eye to the center of that small region of the retina to which the sharpest visual perceptions are confined—the *fovea centralis*—lies wholly on the temporal side of the geometrical axis of the eye and inclined to it at an angle of $4^{\circ}2$; moreover, as necessarily involved with this assumption, that a line drawn outwards from the first nodal point to the point of fixation lies wholly on the nasal side of the axis at the same angle of inclination. This angle we may call, for convenience, the constant of collimation for the normal or schematic eye (H. p. 140).

Closely connected with the constant of collimation in the discussion of a variety of optical phenomena which I shall con-

sider later, is the question of the position of the pupil of the eye. Here too, we lack sufficient data for establishing any conclusion. As far as is known to me, only three eyes have been investigated in this particular, and all of these by Helmholtz (H. p. 29); and as he found in two of the three that the center of the pupil falls very near the axis of vision, and in the third very near the axis of the eye, no result could be less determinate. Were the base of the cornea centered upon its axis of rotation as Helmholtz concluded from his limited number of observations (H. p. 19, relation of angles α and β), the determination of this element would be very easy; indeed, a simple inspection shows that the pupils of practically all eyes, at least when not dilated, are strongly displaced towards the nasal side of the iris. But we found no such simple relation between the axes of the cornea and of the iris; hence it seemed necessary to make a rather extended series of measures for a foundation for precise conclusions.

Helmholtz's method of determining this element by use of his ophthalmometer is somewhat laborious and subject to considerable uncertainties, if not to errors, from changes in pupilar diameter during the measurements. This consideration, together with the fact that statistical information founded upon numerous observations of inoderate accuracy is of far greater value than an accurate determination of individual peculiarities, led me to adopt a different method, which may be described as follows.

A telescope provided with a filar micrometer is placed at a distance from the eye to be measured, which is large compared to the linear dimensions of the eye. The telescope has directly below its objective a small adjustable mirror which, illuminated by a conveniently placed light, serves as a luminous source itself. When the observed eye is fixed upon the middle of the objective of the telescope, the observer sees, with properly adjusted telescope, a sharply defined image of the pupil with a bright point image of the mirror near its center. Two parallel wires of the micrometer are brought within a convenient small distance of each other, and the telescope so directed that these wires appear to be symmetrically placed upon the pupil; then the point image will, in general, appear to lie slightly on the nasal side of a point midway between the wires. In a few cases the bright point will appear exactly half way between the wires, and even, in very exceptional cases, with a very slight displacement towards the temporal side.

Fig. 1 illustrates the general appearance when the nose lies in the direction indicated by the arrow. When a satisfactory adjustment of this kind is secured, an estimate is made of the apparent displacement of the center of the pupil towards the

will lie on the line Cb , which is essentially parallel to n, a , at a point midway between C and the surface of the cornea. Now if the center of the pupil were on the line of vision n, a , it would appear displaced towards the temporal side by a distance equal to the interval separating n, a and Cb , or by $n, C \sin \alpha$. In the schematic eye the distance from n , to C is 0.0861^{cm} . Since α is known for all the eyes observed, the relation of the position of the center of the pupil to the point where the line of vision pierces the plane of the pupil is readily determinable.

The results from the forty-eight eyes thus investigated appeared highly irregular. Yet a careful analysis brings us to a conclusion which may be stated with considerable precision. There were only two eyes in which the centers of the pupils were found to be quite certainly, although by a small amount, on the temporal side of the axis of symmetry, and these belonged to different individuals. On the other hand, only a single eye was found to have the center of its pupil quite distinctly on the nasal side of the line of vision, a peculiarity not shared by its companion. In this exceptional case the apparent displacement towards the nose was strikingly obvious to every casual observer. The mean position of all the forty-eight was almost exactly midway between the axis of symmetry and the line of vision. This relation, so simply stated, was not dependent upon the value of α . This was proved by the fact that when all the observations were arranged in three equal groups according to small, medium and large values of the constant of collimation, each group was found to yield almost exactly the same rule.

The center which has been determined is, of course, the center of the virtual image of the pupil as seen through the cornea; but the rule holds true also for the real position of the pupil. It is not improbable that the center of a dilated pupil is not in quite the same place as one adjusted to a well-lighted room, but that is of minor importance in the questions which have led to this investigation.

For a further study of certain phenomena of vision I shall assume, as a generalization of the schematic eye of Helmholtz:

1st. That its constants as regards accommodation and wavelengths are defined by the tables given in the preceding number of this Journal.

2d. That the collimation error is $4^{\circ}.2$ on the nasal side.

3d. That the pupil is centered on a line which bisects the angle between the axis of symmetry and the line of vision.

Yale University, March, 1905.

ART. XXX.—A New Form of Electrode for Lead Storage Cells; by H. M. DADOURIAN.

It was desired to build up a battery of lead storage cells, to be used in the Sheffield Physical Laboratory, for constant potential. After considering several types of cells, one described by Feussner* was adopted. But the electrodes of these cells

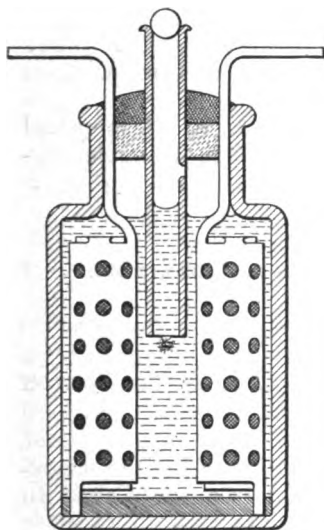


FIG. 1

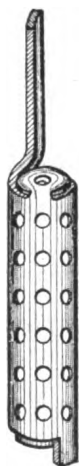


FIG. 2

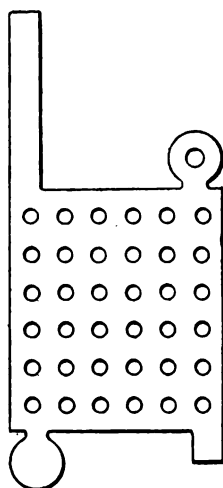


FIG. 3

were inconvenient on account of the falling off of the paste. This objection was done away with by designing a new form of electrode, which has given such satisfactory results that it is thought it may be of interest to others.

A meridian section of a complete cell is shown in fig. 1. Fig. 2 is a perspective view of one of the electrodes, which are 50^{mm} long and are cut out of lead tubing 12^{mm} in diameter.

After being packed up with a paste made of lead oxide (litharge) and sulphuric acid of sp. gr. 1.20, a couple of these electrodes are placed in a glass bottle, 80^{mm} high and 45^{mm} in diameter. The electrodes are held in position by means of a layer of pitch at the bottom and a cork in the neck of the bottle. A small hole in the middle of the glass tube, which is in the center of the bottle, serves as an outlet for the gases which form in the cell.

* Feussner, Sammlung Electrotechnische Vorträge, vol. i, p. 139.

The electrolyte, which is sulphuric acid of sp. gr. 1.20, comes into contact with the paste inside the electrodes through a number of holes, in the latter, of 3^{mm} diameter. A layer of Rowland's Universal wax* pasted on to the cork keeps the acid from creeping out. The electrodes can be made more easily of sheet metal by cutting in the form shown in fig. 3, then rolling it into a cylinder. In case it is desired to make a great number of these cells, a die may be made by which sheet metal can be punched out into the desired shape.

These cells have a capacity of about one ampere-hour and give a potential difference of a little over two volts. They keep this potential difference for several months without recharging.

I wish to express my thanks to Professors C. S. Hastings and H. A. Bumstead for their kind interest in and valuable suggestions on this work.

Sheffield Scientific School of Yale University,
March, 1905.

* Ames and Bliss, *A Manual of Experiments in Physics*, p. 496.

ART. XXXI.—*Chrysoberyl from Canada*; by NEVIL NORTON
EVANS.

THE mineral chrysoberyl is not one of very limited occurrence, but as yet it has not been reported from any Canadian locality, although rocks apparently similar to those in which it is found elsewhere occur over large areas in Canada. When therefore this mineral was identified in a rock from the Province of Quebec, it was thought well to analyse and describe it, so that the species from this locality might be compared with the same species from other places. The facts concerning its occurrence have been kindly supplied by Dr. F. D. Adams of McGill University, who collected the specimens.

The locality where the chrysoberyl was found is situated in the County of Maskinonge in the Province of Quebec, about 100 miles in a northerly direction from Montreal. It is thus beyond the limit of the settled country and in the woods, in a district which has not as yet been surveyed into townships. The spot is situated on the Rivière du Poste, a tributary of the River Matawin; this river in its turn is a tributary of the St. Maurice River, which runs into the St. Lawrence at the town of Three Rivers. It is about one mile below the forks of the Rivière du Poste, where the streams from Lac Long and Lac Clair run together, and is thus about thirteen miles in a straight line north of the point where the Rivière du Poste

joins the Matawin. This whole region forms part of the great Laurentian peneplain and is underlain by Laurentian gneisses which, in this district, hold in places a few small bands of crystalline limestones. At the locality where the chrysoberyl occurs, the country rock consists of a series of quartzose gneisses; these present a considerable variation in character, being often highly garnetiferous, and they are associated with bands of quartzites. The whole series strikes N. 40–45° W. and has a high east dip. The gneiss, where the river crosses it here, is cut by great veins and dikes of pegmatite; these are composed of quartz, orthoclase and a white mica, with black tourmaline and the chrysoberyl as accessory constituents. The pegmatite, as is not uncommonly the case with this rock, often shows a rapid variation in size of grain from place to place. The chrysoberyl is not abundant, but occurs in well-defined crystals.

The rock specimen brought to Montreal contained two individuals of the chrysoberyl; careful chipping brought out the larger in two fragments and some small chips. The two principal fragments were fitted together and weighed 55 grams. This individual, about half of which is uninjured, has almost exactly the form of a hexagonal prism, apparently quite similar to the one figured in Dana's System of Mineralogy, 1885, fig. 155, terminated at each end by a hexagonal pyramid and end face; it measures an inch and a half across and an inch and a quarter in the direction of the pseudo principal axis; the faces of the pseudo-prism, three of which are almost perfect, give an angle of 120° with the contact goniometer (they are not sufficiently smooth for more accurate measurement), and a seam, running vertically through the middles of two opposite prism faces, two of the pyramid faces, and the end faces, seems to be a plane along which the crystal has at one time been fractured, one-half having been slid along about 1/25 inch from its original position; there is, however, no sign of diminished coherence along this plane now. The material of the crystal is apparently fairly pure except for thin films of iron oxide running through it, and some orthoclase which penetrates it on one side.

The cleanest of the chips were chosen for analysis and were ground to a very fine powder in a specially hardened steel mortar; the powder was subsequently boiled with hydrochloric acid, filtered, washed and dried, to free it from the very considerable quantity of steel abraded from the mortar. The method of analysis employed was a slight modification of that given by Penfield and Harper in this Journal (3), xxxii, p. 114 (1886). After several preliminary trials, two analyses were made of the mineral, in each of which about 0.15 grams of the

powder was fused in a platinum crucible for several hours with a large quantity of potassium disulphate, the fusion was extracted with dilute sulphuric acid, and the insoluble material, apparently silica, was filtered out and weighed. It amounted to a few tenths of a per cent and was deducted from the weight of mineral originally dissolved, the percentage of the other constituents being calculated to the remainder. The iron, alumina and beryllia were then precipitated with ammonia, the precipitate washed and redissolved in hydrochloric acid, the solution being then evaporated in a porcelain dish until crystallization just commenced. To this an excess of a strong solution of sodium hydrate, prepared from the metal in platinum, was added; the porcelain dish was used here, as several experiments showed that platinum dishes were attacked to a considerable extent. The mixture was diluted somewhat with cold water, and filtered; the precipitate was redissolved in hydrochloric acid and subjected to the same treatment as before, the filtrate obtained being added to that previously obtained. The precipitate was redissolved, reprecipitated with ammonia and treated in the usual way, giving the iron. The combined filtrates from the two precipitations by sodium hydrate were poured into a liter of boiling water, the boiling continued one hour, and the perfectly white beryllia filtered out, washed, ignited and weighed. The filtrate from the beryllia was boiled again for a short time to make sure that the precipitation of beryllia was complete, was then slightly acidified with hydrochloric acid, evaporated to a small bulk, and the alumina precipitated with ammonia and determined in the usual way. Tests were applied for calcium and magnesium, but neither was found.

The two analyses agreed very closely and the mean was as follows:

BeO	17.78%
Al ₂ O ₃	76.76
Fe ₂ O ₃	6.07
	<hr/>
	100.61

The specific gravity of the mineral was 3.52.

The iron was all calculated as ferric, and this probably accounts in part for the results being high, but no method could be devised for determining the ferrous iron present. No doubt also small quantities of material were dissolved from the dishes and beakers used; their use, however, seemed unavoidable, as platinum was attacked to such a marked extent.

Macdonald Chemical Department,
McGill University, Montreal.

ART. XXXII.—*Souesite*, a native iron-nickel alloy occurring in the auriferous gravels of the Fraser, province of British Columbia, Canada; by G. CHR. HOFFMANN, of the Geological Survey of Canada.

[Communicated by permission of the Acting Director, Dr. R. Bell.]

IN washing the material obtained in dredging for gold in the Fraser river, two miles below Lillooet, Lillooet district, in the province of British Columbia, it has been found that there remains, at the time of cleaning up, a fine, heavy, greyish sand, having a metallic aspect. A sample of this sand, which was sent to the writer for identification, has been examined and found to consist, essentially, of an aggregation of small, very irregular-shaped, rounded grains of an iron-nickel alloy and small to minute, flattened, rounded, steel-grey, glistening scales of native platinum; intermingled with which were some minute, bright, steel-grey colored, irregular-shaped, flattened grains of iridosmine, a few flattened grains of native gold, some minute, partially rounded, crystals of magnetite, a few equally small grains of ilmenite, and a few particles of quartz and of garnet. Of the foregoing, the grains of the iron-nickel alloy constituted, approximately, forty-seven per cent, and those of the native platinum forty-three per cent, by weight, of the whole; the grains of iridosmine, native gold, magnetite, ilmenite, and of quartz and garnet, making up the balance of ten per cent.

This iron-nickel alloy occurs, as above described, in the form of small, very irregular-shaped, rounded grains, the largest not exceeding a millimeter and a half in diameter, whilst many, indeed the greater number, were of far smaller dimensions, and others were of microscopic minuteness. It has a faint yellowish steel-grey color, and a submetallic lustre; is strongly magnetic, and malleable. Its specific gravity, at 15.5° C., is 8.215. The mineral is but very slightly acted upon by hydrochloric acid in the cold; upon the application of heat, however, it very slowly passes into solution. It is readily attacked by dilute nitric acid, even in the cold, and is easily and completely dissolved by it on heating.

The mean of two very closely concordant analyses, conducted by Mr. F. G. Wait, upon very carefully selected material, showed it to have the following composition:—

Nickel	75.50
Cobalt	none.
Iron	22.02
Copper	1.20
Insoluble siliceous matter..	1.16

99.88

Deducting the insoluble siliceous matter, and recalculating the remaining constituents for one hundred parts, we obtain, as representing the composition of the mineral:—

Nickel	76.48
Iron	22.30
Copper	1.22
	<hr/>
	100.00

There are only two instances on record of a mineral similar to that above described having been met with. One of these being the nickeliferous iron called "awaruite," referred to by W. Skey (Trans. N. Zeal. Inst., vol. 18, p. 401, 1885) as having been found, associated with gold, platinum, cassiterite, chromite, and magnetite, in the drift of the Gorge river, a stream flowing into Awarua Bay, on the west coast of the South Island of New Zealand; and the other, the iron-nickel alloy described by A. Sella (Compt. Rend., vol. 112, p. 171, 1891) as occurring in the auriferous sands of the Elvo, a mountain-stream, near Biella, Piedmont, Italy.

As tending to facilitate a comparison of these three, apparently closely related, minerals with each other, their analyses are here given in a tabular form,—(1) being the analysis of the nickeliferous iron "awaruite"; (2) that of the iron-nickel alloy from the Elvo, Piedmont; and (3) the analysis, after deducting some insoluble siliceous matter and recalculating the remaining constituents for one hundred parts, of the iron-nickel alloy from the Fraser river, province of British Columbia.

	G	Fe	Ni	Co	Cu	S	SiO ₂	
(1)	8.1	31.02	67.63	0.70	..	0.22	0.43	= 100.0
(2)	7.8	26.60	75.20*	..	..	..	..	= 101.8
(3)	8.215	22.30	76.48	..	1.22	..	..	= 100.0

The writer would suggest that this mineral be named "souesite," after Mr. F. Soues—to whom he is indebted for the sample sent for identification—to distinguish this find from that of other naturally occurring iron-nickel alloys.

* Nickel, with some cobalt.

ART. XXXIII.—*On the Absence of Helium from Carnotite ;*
by E. P. ADAMS.

THE experiments of Sir William Ramsay and Soddy on the formation of helium from the radium emanation account very readily for the well-known fact that the minerals which contain helium in appreciable quantity contain as well one or more of the radio-active elements. It might therefore be expected that all radio-active minerals should contain helium.

I have recently been testing various specimens of carnotite to determine whether or not helium is present in them. Carnotite promises to become an important source of radium ; certain specimens have been found which have a radio-activity 1·6 times that of metallic uranium, although it appears to be difficult to obtain large quantities of mineral of such high activity. On heating in vacuo several grams of this carnotite, considerable quantities of carbon dioxide and water were driven off, and when these were absorbed by caustic potash and phosphorus pentoxide respectively, only the nitrogen spectrum could be observed when an electric discharge was sent through a vacuum tube connected to the pump ; no difficulty was found in obtaining the helium spectrum when only a tenth as much pitchblende, monazite sand, or thorianite* was used.

The quantity of gas which was obtained from this amount of carnotite was so small that it was thought worth while to work with a larger quantity of the mineral. For this purpose, 300 grams of carnotite of activity 0·8 times metallic uranium was heated at a red heat in vacuo for three hours, and after absorbing the carbon dioxide by caustic potash, about 10^{cc} of a gas remained. On sparking this, after adding oxygen, in order to absorb the nitrogen present, a rapid decrease in volume took place, and when finally the excess of oxygen was absorbed by means of phosphorus, only about 0·1^{cc} of a gas remained. This when introduced into a spectrum tube showed the characteristic red spectrum of argon. It was observed that the greater part of the gas, aside from the carbon dioxide, was given off on the first gentle heating, and it is therefore probable that the argon was associated with the air held in the powdered mineral, which was completely driven off only on heating it.

It therefore appears that if helium is contained in carnotite at all, it exists in far smaller amount than would be expected from the quantity of radium present. But it is probable that

* The recently discovered mineral from Ceylon, containing about 75 per cent of thorium, kindly supplied by Dr. George F. Kunz for this purpose.

this absence of helium may be explained by the physical properties of the mineral. Carnotite is a very fine powder which is usually found disseminated through sandstone. Now even the most compact specimens of this sandstone containing carnotite are exceedingly permeable to gases. This was shown by closing one end of a glass tube with a piece of the mineral about 2^{cm} in thickness, and filling it with illuminating gas over water. In a few minutes the water rose a distance of 6–7^{cm} in the tube. If we then assume helium to be formed in this mineral by the disintegration of the radium, it appears reasonable to suppose that it rapidly diffuses away. The minerals that contain helium are known to be massive, impervious substances, which are therefore able to retain the helium formed in them.

This explanation of the absence of helium from carnotite seems to be supported by the views of Travers* on the state in which helium exists in minerals. According to him, the helium is present in the minerals in a state of supersaturated solid solution; the minerals being impermeable to the gas at ordinary temperatures, the velocity with which equilibrium is established between the helium in solution and the helium in the gaseous phase is very small, but increases rapidly with rise of temperature. In the case of carnotite, however, the mineral is permeable to the gas even at ordinary temperatures, and therefore we could not expect to find any appreciable amount of helium in this mineral.

Princeton University, Physical Laboratory.

* *Nature*, Jan. 12, 1905.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Properties of Methane*.—In preparing pure "marsh gas," MOISSAN has made use of crystallized aluminium carbide made by heating aluminium with carbon in the electric furnace, then dissolving the excess of aluminium by treatment with hydrochloric acid at 0° , washing with ice-water, dry alcohol and ether, and drying in a vacuum. The aluminium carbide, thus purified, was allowed to act upon water at ordinary temperature in order to produce the methane gas. The gas was then liquefied and solidified, and from the solid product pure gas was obtained for experimental purposes. Eudiometric analysis, by explosion with oxygen, and subsequent absorption of carbon dioxide, gave results agreeing very closely with theory. The density, by direct weighing in comparison with air, was found to be .5540 and .5554 as the results of two determinations, which agree very closely with the theoretical density, and are a little lower than that previously found by Thomson and by Schlöesing (.558). When methane was brought into a tube surrounded with liquid air, it solidified at first in a transparent form, like glass; but after a few moments it suddenly crystallized in white needles. It was found to melt at -184° and to boil at -164° . It was found that methane always has a mild, slightly alliaceous odor, which cannot be attributed to impurities. Experiments showed that solid methane is attacked by liquid fluorine at -187° with explosive violence, similar to the action of solid fluorine upon liquid hydrogen. This is another case, therefore, where chemical affinity persists at very low temperatures.—*Comptes Rendus*, cxl, 407. H. L. W.

2. *Silicide of Carbon in the Cañon Diablo Meteorite*.—The fact that MOISSAN has found the substance commonly called carborundum in the residue obtained by dissolving 53 kg. of this meteorite has already been noticed in this Journal. The first announcement of this discovery was perhaps not entirely convincing, as it was based merely upon finding crystals exactly resembling silicide of carbon. Further examination has enabled Moissan to show, after separating the minute crystals by means of a heavy solution, that they possess the physical and chemical properties of the compound, and also that they are composed of silicon and carbon. There is now no doubt, therefore, that this interesting compound, previously known only as a product of the electric furnace, actually occurs in nature.—*Comptes Rendus*, cxl, 405. H. L. W.

3. *A New Process for Detecting Ammonia in Water*.—TEILLOT and TURCHET take 20 or 30^{ccm} of the water to be tested in a test-tube, then add three drops of a ten per cent solution of potassium iodide and two drops of a concentrated solution of an alkaline hypochlorite (commercial Javel's solution). When ammonia is

present, a black coloration is immediately produced, due to the formation of nitrogen iodide. In doubtful cases, where iodine may be set free, a slight excess of the hypochlorite is added in order to dissolve the iodine. The color is sufficiently stable to allow of calorimetric comparison with known amounts of ammonium chloride solution. The authors claim that foreign substances interfere with this reaction less than with Nessler's test, and that other nitrogenous substances do not yield the same reaction.—*Comptes Rendus*, cxi, 374.

H. L. W.

4. *Radio-tellurium*.—MARCKWALD has worked up the crude tellurium obtained from about 15 tons of pitchblende. By dissolving the material and precipitating with sulphur dioxide, about 16 g. of a mixture of selenium, tellurium and radio-tellurium were obtained. Upon oxidizing this with nitric acid, evaporating to dryness and warming with solution of ammonia, a residue weighing about 3 mg. was obtained, which apparently contained practically all of the radio-active material, and possessed "enormous" activity. It is Marckwald's opinion that his radio-tellurium is a distinct substance, not identical with polonium.—*Berichte*, xxxviii, 391.

H. L. W.

5. *Conversations on Chemistry, Part I, General Chemistry*; by W. OSTWALD. Authorized Translation, by Elizabeth Catherine Ramsay. 12mo, pp. 250. New York, 1905, John Wiley & Sons.—The eminent author was led to write this work, for one reason, on account of the benefit that he derived from using a book of similar character, Stöckhardt's "*Schule der Chemie*," as his first text-book of chemistry. As another reason, he hopes to overcome the tendency to onesidedness due to the great attention paid to organic chemistry at the present time in Germany, by presenting a treatise on general and physical chemistry, since these may be regarded as the foundation for all real chemical education.

The form of dialogue between master and pupil has been adopted, because it appeared to occupy no more space than ordinary description, while the impression made is much more "penetrating and lively." This is going back to a form of text-book considerably used by our grandparents, but, while we may frequently smile at the almost superhuman aptitude of the pupil in asking the proper questions and in making appropriate comments, the impression gained by an examination of this little book is that it is a most excellent and valuable one.

The book under consideration, which is the first part of a series, deals only with common and simple chemical and physical phenomena. No attempt is made here to introduce any chemical theories, but many points of physics are very clearly explained. The experiments presented are very satisfactory ones. The translator has done good work, and few traces of the German idiom are evident; indeed, there is sometimes doubt in regard to the original language used to express youthful astonishment, as, for example, where the pupil exclaims, "Oh, how ripping," upon observing a striking experiment.

H. L. W.

6. *Text-book of Organic Chemistry*; by HENRY LEFFMANN, A.M., M.D. and CHAS. H. LA WALL, Ph.D. Pp. 231. Philadelphia, 1904. (P. Blakiston's Son & Co.)—The work is obviously intended for the use of students of medicine and pharmacy. Throughout the book structural formulas are given, even for such complicated compounds as the purine bodies, cocaine, piperine, camphene, salicin and lecithin. But nowhere is there the slightest suggestion that an accepted structural formula, simple or complicated, is the result of a study of reactions. Asymmetric carbon is referred to and stereochemical formulas printed, but the reason given for the latter is that "as molecules occupy space it is desirable to formulate them on a three-dimensional system." Such treatment is calculated to give an entirely wrong idea of the subject, even though the authors have shown in the main good judgment in selecting the compounds to be treated and have given, usually though not always, the structures commonly accepted by chemists. A student acquires some useful information by studying about the occurrence and physical properties of organic compounds, he learns more by studying those reactions from which are drawn conclusions as to the structure of typical compounds; when he has the elementary knowledge he may even learn something about the behavior of complicated compounds by looking at the accepted structural formulas, but such formulas are confusing and meaningless to one who has not acquired the elementary knowledge. W. J. C.

7. *Electric Inertia*.—Sir Oliver Lodge, in an address before the Institution of Electrical Engineers 1903, calculates the inertia which a small sphere charged with a quantity e of electricity and moving with a velocity u has in virtue of its charge. S. H. BURBURY shows that the magnetic force assumed by Lodge to arise in space from the motion of the sphere is exact if u is supposed to be constant, and also e the charge on the sphere. It is not, however, exact if u or e vary.

Burbury also asks whether it would not be safer to apply other limits of integration than those employed by Lodge. The paper is a keen criticism of the generalities of the theory of electric inertia.—*Phil. Mag.*, Feb., 1905, p. 243-250. J. T.

8. *Double Refractions*.—FERDINAND BRAUN shows various methods by means of which artificial double refraction can be produced. A thin bundle of glass wool threads made into a layer 1^{mm} thick shows changes in light under crossed nicols in a polarization microscope; the phenomena can be controlled by immersing the bundle in various oils. The author describes also a method of making stratified dielectrics, which consists in covering glass plates with collodion films, alternating with films of aloe resin (the collodion films are dipped in the resin). Thirty such plates show the Iceland spar cross, and eighty, the ring. Gelatine plates soaked in water until soft, immersed in methyl-alcohol, and built up in a symmetrical orientation, give beautiful images, such as are produced by biaxial crystals. The

author found that similar preparations had been made by earlier observers, especially Nörremberg, and Bertin. Braun extends their work and shows that one of his preparations 2.8^{mm} thick gave rings equal to those produced by a plate of apatite half as thick; or a plate of calcite, 0.1^{mm} thick.—*Ann. der Physik*, No. 2, 1905, pp. 278–281.

J. T.

9. *Emission Spectra of the Metals in an Electric Oven.*—Spectroscopic observations conducted with the electric arc and spark are conditioned to a great degree by electrical phenomena which are difficult to isolate from the mere effect of heat. A. S. KING has developed an electric oven similar to one used by Liveing and Dewar, in order to excite emission spectra only through heat. The forms of oven are described at length. The vapors of the metals emitting spectra are formed close to the hot carbon electrodes in these ovens. A resistance oven is also described in which the heat developed by the white-hot resistance excites the emission spectra. Many interesting results were obtained which are summed up as follows:

1. The oven affords emission spectra which in intensity differ widely from those obtained in the electric arc.

2. The method is especially suited for the observation of band spectra.

3. The changes in the series spectra of caesium show that the glowing vapor follows the radiation law of solid bodies.

4. Comparison of series lines in arc and spark spectra of different elements shows that changed electrical conditions can work in the same way as changed temperature conditions.

5. The calcium spectrum in the oven shows a particular relationship of the lines H and K which appear weakly only at the highest temperature. The *g*-line shows an unsymmetrical broadening of the reversal so that it appears to be displaced. The vapor of the oven shows a much greater absorption power for *g* than for the other lines of the spectrum; this line varies with the temperature.

6. The homologous pairs in the spectrum of Ca, Sr, Ba, with like magnetic types, are relatively much weaker in the oven than in the arc.

7. The oven spectrum gives new bands in the spectra of Ca, Sr, Ba, and Cu. In the green-band group of Ba, there is an apparent displacement of the position of maximum intensity from band to band.

8. The relative intensities of the Cu-lines of the oven approximate to those in a weak arc; the absence of ultra-violet pairs indicates temperature as the source of the radiation.

9. In many cases only a trace of a substance is sufficient to evoke characteristic lines.

10. It is shown that ionized steam, which arises from the arc but is separated from it, gives the arc spectrum even when it lies outside the path of the current.

11. Water vapor in the oven heightens the intensity of metal lines.—*Ann. der Physik*, No. 2, pp. 360, 381. J. T.

10. *The Dynamics of Particles and of Rigid, Elastic, and Fluid Bodies*; by A. G. WEBSTER. Pp. xii+588. Leipzig, 1904. (B. G. Teubner).—This book is a welcome addition to the long list of text-books on mechanics. The gap between the elementary treatises and the classics of the science is wide and difficult to fill. The mere extent of the field to be covered makes the tasks of compression and selection as important as they are difficult. And at the same time the voluminous literature in each separate department makes a single-volume introductory work giving adequate treatment of the methods (necessarily at the expense of many of the applications) very highly desirable. It is this task that Professor Webster has set himself, and, in the opinion of the writer, very successfully performed.

The field covered is sufficiently indicated in the title. Kinematics is not treated as a separate subject, but is taken up as introductory to each subdivision of dynamics in order. The chapters on the general principles and methods of advanced dynamics are especially to be commended. Students of physics are too often insufficiently acquainted with such matters as generalized coordinates, the calculus of variations, Hamilton's principle, etc.; or if at all it is an academic and not a working knowledge which they possess. For all such the above-mentioned chapters should furnish a valuable guide. The section on rigid dynamics might possibly be criticized as being disproportionately full in the treatment of gyroscopic motion: a fault, if it be a fault, both to be expected and condoned in an author whose original contributions to this subject are so well known. The general theory of the potential function forms the introduction to the section on the dynamics of deformable bodies. This chapter follows very closely the presentation of the same subject in the author's well-known "Theory of Electricity and Magnetism." The remaining chapters of this section,—those on elasticity and hydrodynamics,—are, relatively to their importance, the shortest in the book. They form, however, an excellent introduction to the very extensive literature of these topics.

Typographically and in the matter of illustrations the book is unusually excellent. It appears as the eleventh in the Teubner collection of text-books of the mathematical sciences. L. P. W.

11. *Experimentelle Untersuchung von Gasen*; by M. W. TRAVERS. German translation by T. ESTREICHER. Pp. xii+372. Braunschweig, 1904 (Friedrich Vieweg und Sohn).—This German edition of Professor Travers' invaluable "Experimental Study of Gases" is not a mere translation, but presents considerable matter that is not contained in the English edition of 1902, in addition to being largely rewritten. The book is so well known that it is only necessary here to point out some of the additions which appear in this edition. The chapters on the liquefaction

of gases and on the handling of the same contains much new matter, especially with reference to the liquefaction of hydrogen and the fractional distillation of gas mixtures at low temperatures. All the very recent determinations of the physical constants of the rare gases of the argon group, as well as the new methods used in their measurement, are included. An entire new chapter has been added by the translator on the specific and latent heats of gases, which contains much valuable information both as to methods and results. These constitute the main additions.

As a whole, this German edition can be said to add to the value of a work already indispensable to the worker in gas analysis or low temperature research.

L. P. W.

12. *The Dynamical Theory of Gases*; by J. H. JEANS. Pp. viii, 352. Cambridge, 1904. (University Press.)—In the first five chapters of this book is given the theory of the distribution of velocities and of the partition of energy in conservative systems. Two methods of deriving the law of distribution of velocities are given: the classical method of Maxwell and Boltzmann, and a method devised by the author which is not unlike that of Gibbs (*Elementary Principles in Statistical Mechanics*). Then follow two chapters developing the physical properties of gases as predicted by this theory and the comparisons with experiment. The unsatisfactory result of this comparison, especially in the case of the ratio of the specific heats, is due to the fact that the theory assumes that molecules form conservative systems. This leads to the theory of a non-conservative gas which is treated in the next three chapters. Here for the first time in the book is introduced an hypothesis as to the structure of the molecule. The assumption is made (supported by the evidence of spectroscopy) that the ultimate components of the gas possess a number of isochronous free vibrations. With the aid of this assumption the complete theory is worked out, and the agreement with experiment is shown to be of a very satisfactory nature. Next come six chapters on the various free path phenomena. The book concludes with applications of the theory to planetary atmospheres, molecular aggregation and dissociation, and the calculation of the size of molecules. In the appendices are given tables to aid in the evaluation of the exponential integrals of common occurrence in the kinetic theory.

Altogether this is the most satisfactory treatise on the subject that the writer knows. It is particularly excellent in its treatment of the historic difficulties connected with the question of the partition of energy. The treatment of the non-conservative gas is very original and suggestive. The orderly perspicuous development, the excellent historical perspective, the clear separation of assumption and fact, and the unusual attention paid to the quantitative numerical side of the subject, all contribute to make this one of the notable books of the year.

L. P. W.

13. *Optical Pyrometry*.—A paper by C. W. Waidner and G. K. Burgess in the second number of the Bulletin of the Bureau of Standards (see also p. 91, Jan., 1905) gives a thorough discussion of the subject of optical photometry, both as regards theory and methods. The experimental comparison of the various types of optical pyrometers is particularly thorough and valuable. The authors conclude, on the basis of their experiments, that the several laws of radiation are in quite satisfactory agreement at the highest attainable temperatures and thus serve to define the same scale of temperatures. For example, they state that "it would seem that the radiation laws are still in agreement at the temperature of the arc. Our measurements have given as the black body temperature of the hottest part of the positive crater 3690°, 3680°, and 3720° absolute, as determined with the Holborn-Kurlbaum, Wanner, and Le Chatelier pyrometers, based on the extrapolation of Wien's law. Féry gets for this temperature 3760° by a method based on Stefan's law."

II. GEOLOGY AND MINERALOGY.

1. *Cambrian Brachiopoda with Descriptions of New Genera and Species*; by CHARLES D. WALCOTT. Proc. U. S. National Museum, xxviii, 1905, pp. 227-337.—This is the sixth paper of the preliminary studies for the monograph on the Cambrian Brachiopoda, to be published by the U. S. Geological Survey. In it are described 106 new species, 50 old species, 8 old genera, and the following new genera or subgenera: *Otusia* (type *Orthis sandbergi* Winchell), *Nisusia* (type *Orthis festinata* Billings), *Jamesella* (type *Orthis perpasta* Pompeckj), *Eostrophomena* (type *E. elegantula* new), *Orusia* (type *Orthis lenticularis* Wahlenberg), *Finkelnburgia* (type *F. finkelnburgi* new), *Loperia* (type *L. dougaldensis* new), *Swantonina* (type *Camarella antiquata* Billings), *Rustella* (type *R. edsoni* new), *Curticia* (type *C. elegantula* new), *Quebecia* (type *Obolella circe* Billings), and *Schuchertina* (type *S. cambria* new).

As the generic name *Iphidea* Billings, 1872, was preoccupied by Boyle, 1865, Dr. Walcott here changes the name to *Iphidella*. However, as two other generic names have been proposed for species referred by Walcott to *Iphidella* we are obliged under the rules of nomenclature to replace his by one of these names. The earliest one is Meek's *Micromitra* (type *Iphidea* (?) *sculptilis*), or Beecher's *Paterina* (type *Obolus labradorica*). As *I. sculptilis* has an ornamental surface, it may be well to retain *Micromitra* in a subgeneric sense, in which case we are forced to adopt *Paterina* for the unadorned forms to replace the preoccupied name *Iphidea* Billings.

From the six papers thus far issued, it is evident that Dr. Walcott's monograph is not only to be a monumental volume, but that students of brachiopods will have a firm foundation on which

phylogenies and a final classification of these organisms can be built.

C. S.

2. *Occurrence of Mastodon humboldtii in Northern Mexico.*—A small collection of *Mastodon* material, from near the line of the Chihuahua al Pacifico R. R., was presented to the Yale University Museum in 1902, by Mr. CHARLES SHELDON (Yale 1890). The remains include part of an upper tusk and fragments of a tooth from Guerrero, near Concepcion, in the state of Chihuahua, Mexico; also the head of a femur, which was found about sixty miles from Chihuahua. The tooth may be identified with the third upper molar of *Mastodon humboldtii* Cuv., as the cross-crests show the peculiar "double-trefoil" pattern characteristic of that species, and otherwise agree closely with Prof. Cope's definition of *Mastodon* (= *Dibelodon*) *humboldtii* (Fourth Annual Report, Geol. Surv. Texas). This identification is of considerable interest, inasmuch as Prof. Cope stated (*loc. cit.*) that the supposed occurrence of the species in Mexico was based on a misapprehension, the specimen from Mexico described as *M. humboldtii* by Von Meyer (*Palaeontographica*, 1867) being subsequently arranged by Cope under the new species *Dibelodon tropicus*.

G. F. EATON.

3. *Petrography and Geology of the Igneous Rocks of the Highwood Mts., Montana*; by L. V. PIRSSON. Bull. 237, U. S. Geol. Surv., 1905, 208 pp., 7 pls.—The Highwood Mountains form a group of much eroded volcanoes situated on the great plains of Montana within the great bend on the Missouri River. They present stocks of granular rocks filling the old conduits, which are surrounded by a vast network of radial dikes. There are some intruded sheets and masses of extrusive flows, breccias and tuffs, remnants of the former cones. On the southeast there is an interesting region of intruded laccoliths which affords examples of rock differentiation in place.

The igneous rocks composing these varied masses are of alkalic types, mostly basic in character with a prevailing dominance of potash in the alkalies. They afford a number of interesting and novel kinds, some of which, such as shonkinite and missourite, have been previously described by the author in conjunction with Mr. W. H. WEED. In this bulletin the geology of all these occurrences is described and the petrography of the different rocks given in full detail with chemical analyses. The new quantitative system of classification is used, giving an opportunity of testing its practical working. In conclusion, the bearing of the facts observed on the origin and differentiation of igneous rocks is treated.

4. *Red Beryl from Utah*; by W. F. HILLERAND. (Communicated.)—From Mr. Maynard Bixby of Salt Lake City, there have recently been received three crystals of beryl which because of their color—a rich raspberry-red—seem to merit notice. The specimens show single crystals of short prismatic or tabular shape, 3 millimeters in height and up to 7 millimeters across the basal plane, implanted on imperfect topaz crystals. According to Mr. W. T. Schaller, the only other forms are those of prisms of

the first and second order, the habit being the usual one for beryl, and the specific gravity is 2.65. The color is presumably due to manganese, of which the crystals contain a very appreciable amount. Approximate chemical determinations leave no doubt as to the identity of the species. The locality of occurrence is that made known by the discovery of bixbyite, about 35 miles southwest from Simpson Springs, Utah, in the Dugway Range. The matrix is rhyolite, and the chief associates, according to Mr. Bixby, are topaz, bixbyite and altered garnets.

5. *The Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada*; by ALFRED ERNEST BARLOW. 236 pp., with 24 plates and five geological maps. From vol. xiv of the Annual Report of the Geological Survey of Canada. Part H.—The importance of the Sudbury mines will be appreciated when it is stated that they now give Canada the position of the largest producer of nickel in the world. This report by Mr. Barlow is an admirable presentation of the whole subject, describing the geological relations and composition of the deposits, discussing their origin and also giving an account of the methods of mining and metallurgical processes. A summary is also added of the occurrence of nickel in other parts of the world, with particular reference to the Scandinavian deposits which in many respects are strikingly similar to those of Canada.

The nickel- and copper-bearing ore bodies consist essentially of pyrrhotite, by far the predominant constituent, chalcopyrite in much smaller amount and also pyrite. The nickel, however, is almost entirely confined to the species pentlandite, which is in general very uniformly distributed throughout the whole mass. Both the pyrrhotite and pyrite carry nickel in small amount, but it is not certain that it really belongs to the composition of these minerals, some authorities referring it here also to admixed pentlandite. Besides the species mentioned, the following nickel minerals also occur in limited amount: millerite, polydymite, niccolite, gersdorffite and marcasite. Other associated species are the following: morenosite, annabergite, sperrylite, danaite, smaltite, galena, chalcocite, bornite, magnetite, cassiterite, native copper, native gold, graphite, cubanite and some others.

The deposits occur in connection with certain eruptive rocks. These are discussed by the author under two divisions:

(1) A basic portion:—Including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel- and copper-bearing sulphides are immediately associated.

(2) An acidic portion:—Comprising large areas of rock of granitic type, with well-marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and feldspar, known as granophyre or micropegmatite, having suggested the name "micropegmatite," by which this rock is now generally known.

The origin of the ore deposits is discussed in detail and the author states his belief that the Sudbury deposits, like those of

Norway described by Vogt, are of igneous origin, being the direct product of the differentiation of a basic igneous magma modified to some extent by certain secondary processes.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Studies in General Physiology*; by JACQUES LOEB. The Decennial Publications of the University of Chicago, 2 vols., 782 pp. University of Chicago Press, 1905.—These studies include a series of papers collected from Professor Loeb's important contributions to general physiology during the past fifteen years. The range of topics selected is broad; yet, in the words of the author, "a single leading idea permeates all the papers of this collection, namely, that it is possible to get the life-phenomena under our control, and that such control and nothing else is the aim of biology." The present form of presentation will be especially welcome to many readers, since most of the papers are here given in English translation for the first time. In this collection will be found the well-known researches of Loeb on the heliotropism of animals and on heteromorphosis, various papers in the field of physiological morphology—the study of the connection between chemical changes and the process of organization in living matter; while most of one volume is devoted to investigations involving the application of the modern physical chemistry to the solution of biological problems. Prominent among these are studies on the physiological rôle of ions, and the splendid observations on artificial parthenogenesis. The reader may, at times, be inclined to hesitate in accepting the generalizations of the author; but one must admire the enthusiasm and untiring energy of the investigator, the wealth of important observations presented, and the originality of treatment which fundamental problems receive. Professor Loeb has won an enviable reputation which is well deserved. The University of Chicago is to be congratulated in the publication of these commemorative volumes.

L. B. M.

2. *The Birds of North and Middle America*; by ROBERT RIDGWAY. Part III, pp. xx, 801 with 19 plates. Bulletin No. 50 of the U. S. National Museum.—This is the third part of this important work, already noticed in these pages; it includes the species of fifteen families from the Wagtails and Pipits (Motacillidæ) to the Warblers (Sylviidæ). The three volumes already published include some twelve hundred and fifty species and subspecies, that is about two-fifths of all the North and Middle American Birds.

3. *British Museum Catalogue:—A Synonymic Catalogue of Orthoptera*; by W. F. KIRBY. Vol. I, pp. x, 501. London, 1904.—The author, who has recently carried through a re-arrangement of the Orthoptera of the British Museum, has now prepared a complete catalogue of the Order. This first volume contains the species of five families and the remaining three will be included in one, or possibly two, additional volumes. This work will be of great value to all students of Entomology.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIV.—*On the Physiographic Improbability of Land at the North Pole*; by J. W. SPENCER, A.M., Ph.D.

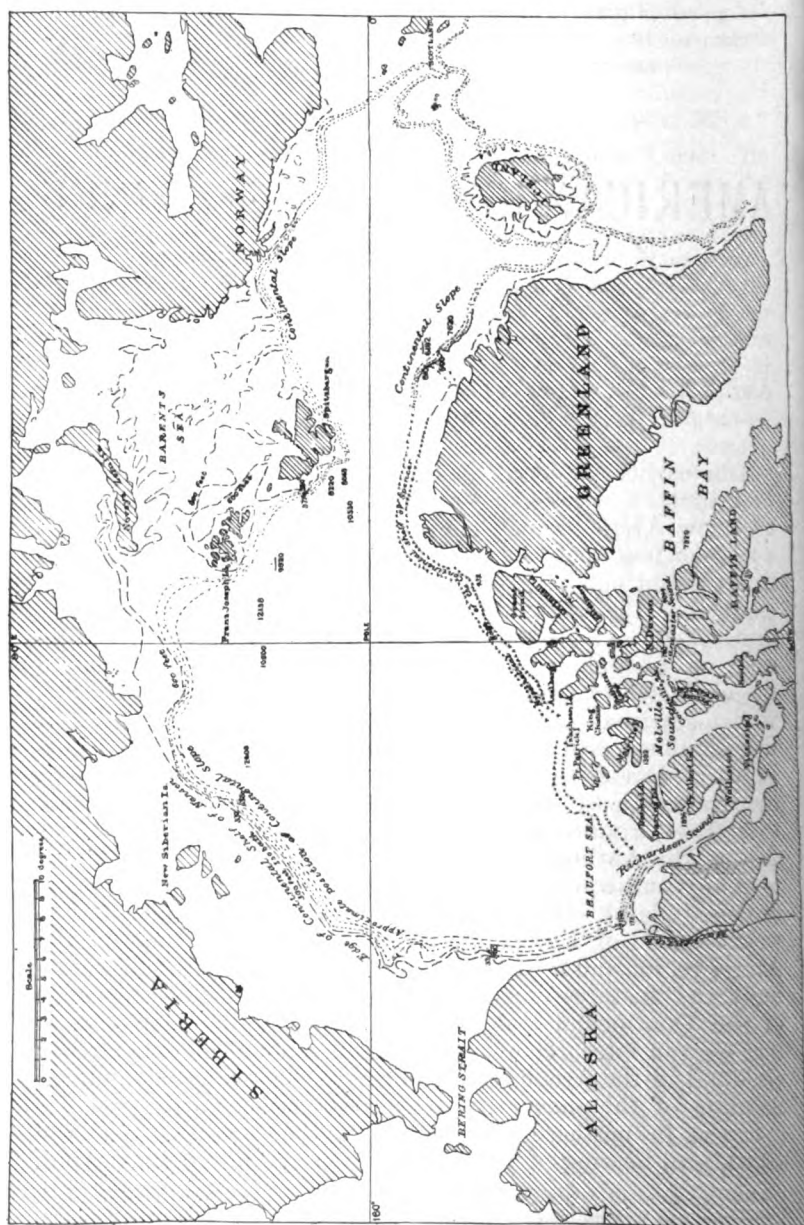
THE earlier explorers had little to guide them, but they brought back occasional soundings, which seemed to indicate a shallow Arctic basin. The drift wood suggested that it was a more or less open sea, beneath the ice floes, even though its depth might not be great. Some soundings were of unusual depth, but their importance, not being known, was entirely overlooked. The soundings in the Arctic region were insufficient of themselves to suggest their own explanation, before the character of drowned channels was understood. Indeed, while occasional valleys channeling the submerged border of the continent had been noted by Dana, Lindenkohl, Milne-Edwards, Davidson, Issel, the present writer, Upham, and others, the systematic study of these features really dates back only to 1893-4, resulting in the publication of the "Reconstruction of the Antillean Continent."* This has been the pioneer of many subsequent contributions on submarine valleys and drowned plains. The same features have been studied on the western side of Europe by Prof. Edward Hull,† and in the Arctic region and farther south by Prof. F. Nansen.‡ According to the features of submarine valleys channeling the edge of the Continental mass are now pretty well understood, so that we can interpret even the limited amount of data already obtained in the Arctic region and have some reasonable understanding of the phenomena which they indicate.

I was in northern Norway when the Ziegler expedition sailed, and hearing of their expectation of finding Polar land,

* By the present writer, Bull. Geol. Soc. Am., vol. vi, pp. 103-140, 1894.

† Numerous papers, mostly published in Trans. Victoria Institute, London, 1898-1902.

‡ On Bathymetrical features, Continental Shelves and Oscillations, Christiania, 1904, pp. 232, plates 28.



I felt that disappointment was in store for them; for Dr. Nansen's great discovery of a profound Arctic basin, immediately beyond the border of the continental shelf, precluded the probability of finding land between Franz Joseph Land and the Pole, or indeed along this line for a thousand miles beyond, until approaching the embouchure of the Mackenzie River, although to the left of this line the continental shelf north of Greenland, bearing perhaps an island, might extend far polarward. Nansen had found the Polar basin to reach a depth of 12,000 feet or more. This would have to be crossed by any expedition from the European side and here no portable sounding apparatus could be effective until approaching the American shelf beyond the deep basin itself. But had the undertaking been made from Grant Land, soundings to a depth of 3000 feet or less would have surely revealed the rapidly increasing depth of the slope from the continental shelf to the abyss of the basin, out of which no land could be expected to rise. Thus the character of the Polar district would have been discovered, perhaps without reaching to within some hundreds of miles of the Pole, depending upon whether the shelf extends far north of the known land or not. If the Ziegler expedition were for the purpose of adding to our knowledge, it is to me astounding that the route chosen should have been approved of by the advisers, knowing of the deep sea north of Europe, even without such analysis of the subject as has since been published by Nansen, or is here set forth. If the voyage were only one of adventure to reach an icy Pole without any ostensible scientific object, then I give no opinion as to the route taken. These remarks directed to an actual expedition would equally apply to the proposed one of the Duke of Orleans. They are written in the hope that future Polar explorers will take cognizance of the scientific submarine topography, avoiding useless expeditions and devoting their efforts to extending scientific knowledge.

To define the features around the Arctic basin, I should draw an axis from Cape Bathurst, passing close to Bank's Land, Prince Patrick's Land, the Pole, and on to Franz Joseph Land and Novaya Zemlia, thus dividing it into two unequal lobes. The one on the Siberian side is bounded by low lands, with few islands, all of inconsiderable height in front. The confines of the other lobe have bold features in the mountainous islands of Novaya Zemlia, Franz Joseph Land, Spitzbergen, North Greenland, Grinnell Land, Sverdrup's New Land to Prince Patrick's Land and Bank's Land, which have less abrupt features.

In front of the Siberian plains and north of Bering Straits, Dr. Nansen has shown from his own and other soundings that

the continental shelf has a breadth of 300 or 350 nautical miles (see map). Its outer margin is at a depth of 300 feet, beyond which is the rapid descent of the continental slope. In front of Spitzbergen, and apparently adjacent to Franz Joseph archipelago, the shelf has a breadth of only about 30 miles. Its border recedes and forms an embayment east of Novaya Zemlia. North of the New Siberian Islands, Nansen found that the submergence of the continental slope increased from about 300 feet to 6000 feet in 30 miles. A similar gradient has been found adjacent to Spitzbergen. Soundings in sufficient numbers have been taken to establish the existence of the broad shelf, with a few others suggesting its border, as for instance, where in proceeding outward the sea suddenly deepens from 300 feet to 700–800 feet. Thus defined, Nansen's map shows a direct line in front of Bering Straits to north of Alaska. Here the continent encroaches upon and greatly contracts the shelf,—an important analytical feature. The shelf appears to be reduced to a breadth of perhaps 40 miles. The Arctic basin does not approach Bering Straits, which is only a shallow lateral trough from the basin itself, but ends in Beaumont Sea, between Prince Patrick's Land and Alaska, where the Mackenzie River, after passing through its own broad embayment or delta, extends to a submarine valley discovered, so far, to a depth of over 1140 feet beneath sea level, thus deeply incising the shelf. In the broad channel between Bank's and Bering Lands and the continent, which (unless it is otherwise named, and the charts do not show it) might appropriately be called Richardson Sound, after its explorer (1848), the submarine valley has a depth of 1836 feet, near the head of a branch fjord, at a point 175 miles within the line of the islands.

Lower down the sound are a number of deep soundings, but they do not reach the bottom in the central axis. Beyond, in McClure's Strait, which separates the eastern side of Bank's Land from Melville Island, the fjord attains a depth of 1362 feet and more, at a point 200 miles within the line of the islands. Here we have found the evidence of deep submarine valleys or fjords entering Beaumont Sea from three different directions, and very much deeper than the submergence of the great continental shelf of the Arctic basin. Further proof is not needed to establish the fact that Beaumont Sea is a broad profound valley leading to the Polar basin, though the depth is not known. Also, that the continental shelf is deeply channelled by the valleys. Now, as we have learned from the analysis of the submarine valleys or fjords off Norway and both coasts of America, the border of the continental shelves does not usually exceed a distance of more than from 40 to 100 miles beyond the outer line of the land or islands. Off

Spain and Portugal the shelf is reduced to 6–20 miles. While the Norwegian channel is much longer, yet it hardly forms an exception to the rule, for the edge of the continental shelf, even here, is within the line of the land between Scotland and Norway. Even now we have sufficient data to show that the edge of the lower platform at a depth of 1200 feet (like in Barentz Sea) does not exceed a distance of 60 to 100 miles from land off East Greenland and in Baffin Bay. From my familiarity with the study of continental shelves, the margin of that beyond even the lower part of Prince Patrick's Land should not be expected to extend more than a hundred miles, if indeed so much, with such a deep channel extending far within the line of the islands. Neither the Meham nor the McClintock expeditions found land beyond the northern side of Prince Patrick's Land. These fjords are in the western side of the archipelago. Four hundred miles farther east (south of the western end of North Devon) in the head of Lancaster Sound we find another fjord with a depth of 780 feet deepening in 150 miles to over 4000 feet at a point 50 miles within the line of the islands, while other soundings show the shelf to attain a breadth of only a few miles in this part of Baffin Bay adjacent to the deep fjord, but elsewhere it reaches to 100 miles. About 160 miles north of Lancaster Sound, in Cardigan Strait, on the Arctic side of the *col* between North Devon and North Kent, the depth of the fjord exceeds 2400 feet. This point is situated about 250 miles within the line of Sverdrup's New Land, showing that here is another deep channel trending to the Arctic basin. Now with even the few soundings before us (and there are many more not cited here) the fjord-like character of the archipelago cannot be questioned. It is a dissected plateau region (much of which is now 2000 or 3000 feet high, subsequently submerged in part—a region fashioned by atmospheric agents whether now above or below sea level. As the depths mentioned are far within the land line, and in the case of one sound a depth of over 4000 feet occurs even 50 miles within the land line, there is every reason to expect similar depths nearer the mouths of the other fjords mentioned. Where the submarine valleys have attained considerable depths within the land line the shelf should be relatively narrow; and judging from the position of Sogne fjord (nearly 4000 feet deep) I should not expect to find the breadth of the shelf exceeding 50 miles in front of Sverdrup's New Land, as much of the region is a weatherworn plateau. One sounding north of Grant Land strengthens this view. At about 30 miles off the land the sounding shows 432 feet, somewhat in excess of the submergence of the Arctic continental shelf wherever known off the Siberian coast. It would seem that the edge is being approached. Nansen has pointed

out the remarkable uniformity of the shelf in the Polar basin. Continental shelves are characteristically narrower in front of bold highlands than where they fringe low plains as on the other side of the Polar basin. Apparently the question of the formation of the continental shelf in one part of the Arctic cannot be separated from the rest of it. No land was discerned beyond Prince Patrick's or from Sverdrup's New Land.

From the absence of land for a hundred miles, from the occurrence of the sea depth at 432 feet thirty miles from land, and from the characteristic of narrow shelves in front of high lands, I suspect that Commander Peary passed the edge of the shelf and was perhaps over the deep basin, as he would have been in front of Spitzbergen. From this consideration and from the feature of limitation of the continental shelves being indicated by the presence of deep fjords as found among the islands of the archipelago, and from the characteristics of the platforms in front of high lands, I am inclined to place a theoretical limit of from 50 to 100 miles as the breadth of the shelf in front of the known islands, without the expectation of finding any great islands farther north. If this approximation, based upon physiographic information of no mean value, be correct, there would still remain a distance of 300 or 350 nautical miles between the edge of the shelf north of Grant Land and the Pole, beneath the ice of which obtains the deep basin. The edge of the shelf, indicating the limit of the insular extension of continental lands, wherever found, precludes the probability of land beyond, rising out of a deep sea basin.

Having found a working hypothesis from the physiographic features, other phenomena in support of the hypothesis based on the submarine topography have been mentioned by Dr. Nansen. Along the course of the Fram, at depths of more than 800-900 meters, colder heavy bottom water was found, above that affected by subterranean heat, but beneath the overlying stratum of warmer water. It must have cooled down somewhere in the unknown Arctic basin, in contact with the cold surface water; and this place of wide extent is somewhere far from the course of the Fram, occupying probably the greater part of the still unknown Polar region. Similar phenomena exist in the Norwegian Sea, where, however, the center of cold has been found. The drift of the ice under the coast of Greenland is much greater than where the ice belt is broader in the Polar sea. These additional phenomena further preclude the idea of Polar land.

I have not touched upon the question of possible land north of Bering Straits. The position is much farther from the Pole than that of the locations considered. Nor has the question of

tides been referred to. This last has been ingeniously discussed by Dr. R. A. Harris.* According to him, the currents set eastward and westward from Bering Straits, which he thinks is caused by land to the north. The tides coming from the east of Greenland (rising two feet) recur near Bennett Island, north of the New Siberian, with the same range. The drift of the Jeannette was accelerated on approaching this locality as if a broad strait were situated here. On the coast of Alaska, the tide is reduced to a few inches, caused, Dr. Harris thinks, by the interference of a large land area. Now Bennett Island is more than 100 miles within the border of the continental shelf. Nansen crossed its edge 200 miles northwest of this point, so there is room for an island of considerable size without the shelf protruding beyond its general outline. Although the outline of the shelf, north of Bering Straits, seems to have been approximated, there may be in front of it a secondary platform, on which remnants of a higher one, surmounted by land, occur with characteristics resembling rather the New Siberian archipelago than Spitzbergen, although this last mass partly rises above a lower platform, as would be the case with part of the hypothetical islands north of Bering Straits. It is only on an extension of the continental shelf that the occurrence of land could be expected, and any great extension of it would disturb the symmetry of its outline, a point which should not be overlooked. If the phenomena described by Dr. Harris really demand a great land mass, physiographically there is no reason why there should not be even a nearly continuous chain of islands from near Bennett Island extending towards Prince Patrick's Land, though it could not occur in front of Beaumont Sea. But I find no ground here for extending land nearer than ten degrees of the Pole. Islands would satisfy the tidal currents off Alaska according to Dr. Harris, though it might not explain the tide rising two feet to Bennett Island. My conclusions agree with those of Sir Clement Markham, quoted by Dr. Harris:—who "does not believe in any land near the Pole, but believes there is land probably in the form of large islands between Prince Patrick's Land and the New Siberian Islands." I should limit their occurrence to a line directly connecting these islands, with no important additions, to the American archipelago, a theory suggested by the enclosed fjords. An island may exist near Simpson cove as suggested by Dr. Harris, perhaps constituting the end of a chain from Bennett Island skirting the edge of the continental shelf.

If I were permitted to plan out an expedition for the purpose of adding to our knowledge of Arctic physiography, it would be somewhat on the following lines, so far as physical

* *Nat. Geog. Mag.*, vol. xv, pp. 255-261, 1904.

conditions would permit. Two expeditions have reached Prince Patrick's Land. Another might enter by Bering Straits, skirt the ice and make close soundings in Beaumont Sea, discover the deeper canyon of Mackenzie River, explore to the bottom Richardson Sound and the channels to Prince Patrick's Land. If the ship could not be drifted past this place, a land and over-ice party with portable sounding apparatus, for depths of 500 fathoms, or if possible a little more, should make the utmost effort to reach a point where the water had either such a depth, or land were found, if the sea continued shallow beyond expectations. A hundred miles have been crossed by Peary; probably so long a journey would not be needed. If the ship could be drifted in the ice north of Prince Patrick's, the sound between this land and Sverdrup's New Land should be explored, for islands or open sea. Else the ship might have to follow the old route through Melville Sound, with an effort to revisit Isachsen Land (one of Sverdrup's New Lands), carrying the ship, or repeating the over-ice sounding expeditions to determine the border of the continental shelf. Such a program should be continued to north of Grant Land, various points of which have been visited, even if the ship could not be worked or drifted in the ice. North of Grant Land, and also Greenland, should be revisited as by Commander Peary, but carrying the sounding apparatus, so that when the edge of the continental shelf shall be reached, the explorer would know when his work was finished and avoid useless adventure. Such an expedition, perhaps requiring several years, should be made to round off Polar explorations. It seems to me to be the only one promising great results, at least of a finishing character. Explorations north of Bering Sea would be farther away, and I have no suggestions to make except to sound well the region traversed, by the ship or sledge party attempting a further voyage.

This little paper is only an application of the study of the deep channels trenching the eastern coastal plains of the continent; which study throws much light upon the subject of the physiography of even the Polar regions. There is also an economic aspect of the question of such submarine physiography, as in the laying of cables, so that they will not swing over the precipices of drowned canyons and consequently collapse. Prof. Davidson has reported ships lost by not being able to drop anchor during storms through being unaware of the adjacent shoal waters, outside of the limits of the drowned channels.

ART. XXXV. — *Bibliography of Submarine Valleys off North America* ; by J. W. SPENCER.

Papers on the Submarine Valleys indenting the Continental Shelf off the American Coast and in the West Indies ; by J. W. SPENCER.

THE appearance of the "Submarine Great Canyon of the Hudson River" has emphasized the absence of easy reference to the scattered contributions where those interested have not continuously been giving the subject their attention. In this case, it may be expressed in the language of a gentleman, a stranger to the writer, who says that he is "now much interested in this particular subject, but has been unable to get hold of any matter regarding it otherwise than a vague popular sketch here and there which has left him about as much in the dark as though he had read only the title." Some of the papers are not of recent appearance. Others have been published abroad. This condition is perhaps sufficient reason to assemble the list of the papers. The subject is one of equal interest in Europe as here, where there would be a greater difficulty in knowing what had appeared on this side of the Atlantic.

In order to call the attention of the American student to what has been done by Prof. Edward Hull and Prof. Fridtjof Nansen, I have prepared somewhat lengthy summaries of their contributions on this subject, as these are more difficult of access here. The writer's investigations are the slow outgrowth of his studies of the origin of the basins of the Great Lakes, which will not be further referred to here. Otherwise, as bearing on the Atlantic border the investigations began with :

1. "High Continental Elevation preceding the Pleistocene Period ;" Bull. Geol. Soc. Am., vol. i, pp. 65-70, 1889 ; Geol. Mag. Lond., III, vol. vii, 1889. (This contains a description of the submarine valleys of the Gulf of St. Lawrence and of Maine to depths of over 3000 feet. The former is now known to be over 5500 feet.)

2. "Terrestrial Subsidence Southeast of the American Continent" (a preliminary notice of the next paper) with map. Bull. Geol. Soc. Am., vol. v, pp. 19-22, 1893.

3. "Reconstruction of the Antillean Continent" with map. Bull. Geol. Soc. Am., vol. vi, pp. 103-140, 1894-5. (Here is a description of the submarine valleys extending beyond the buried channels of great land rivers, and trenching the continental shelf to abyssmal depths, from Cape Hatteras to the Gulf of Mexico and in the Caribbean Sea. The evidences therefrom indicate great Pliocene and Pleistocene elevations, and the land connection of the two Americas. This is the first constructive paper

on the subject, and together with the discussion of the bearings is the foundation of the subsequent work.) Abstract in *Am. Nat.*, vol. xxviii, pp. 881-884. Also an important "Note on Mr. Kummel's review," concerning the gradient of the valleys. *Jour. Geol.*, vol. iii, pp. 497-498, 1895.

4. "The Yumuri Valley of Cuba—a rock basin." *Geol. Mag. Lond.*, IV, vol. i, pp. 499-502, 1894.

5. "Preliminary Notes on the late Connection and Separation of the Pacific Ocean and Gulf of Mexico," *Ib.*, vol. ii, pp. 306-308, 1895.

6. "Geographical Evolution of Cuba," *Bull. Geol. Soc. Am.*, vol. vii, pp. 67-94, 1896 (with more details of the submarine valleys and their geological relationship, terraces, etc.).

7. "On the Continental Elevation of the Glacial Period," *Geol. Mag. Lond.*, IV, vol. v, pp. 32-38, 1898; Abstract *B. A. Rept.* for 1897, pp. 651-652. (This contains a notice of the recurrence of the submarine valleys, on both sides of the North Atlantic and in the Arctic Sea. It was preliminary to No. 23.)

8. "Geological Canals between the Atlantic and Pacific Oceans." Abstract preliminary to No. 9. *Proc. Am. As. Ad. Sc.*, vol. xlv, pp. 139-140. 1896.

9. "Great Changes of Level in Mexico and the Interoceanic Connections," *Bull. Geol. Soc. Am.*, vol. ix, pp. 13-34, 1898. (Here is shown changes of level complementary to those indicated in the submarine valleys.)

10. "Late Formations and Great Changes of Level in Jamaica." *Trans. Can. Inst. Toronto*, vol. v, pp. 324-357, 1898. (With further details of the relationship of the submarine valleys to the land features, of the characteristics of the submarine platforms, of land connections, etc.) Abstract in this *Journal*, IV, vol. vi, pp. 270-272, 1898.

11. "Resemblances between the Declivities of High Plateaus and those of Submarine Antillean Valleys." *Trans. Can. Inst. Ib.*, pp. 359-368. Abstract this *Journal*, IV, vol. vi, pp. 272-273, 1898. (Showing the gradients of both kinds of valleys by steps, an important supplement to the Antillean paper, No. 3.)

12. "The West Indian Bridge between North and South America." *Pop. Sc. Monthly*, vol. liii, pp. 10-30, 1898.

13. "Geological Waterways across Central America," *Ib.*, pp. 577-593.

14. "Prof. Hull's 'Submerged Platform of Western Europe.'" *Geol. Mag.*, *Lond.*, IV, vol. vi, pp. 16-18, 1899.

15. "Mr. Huddleston's 'On the Eastern Margin of the North Atlantic Basin.'" *Ib.*, pp. 559-566. (A reply to his criticism of Prof. Hull's work.)

16. "The Windward Islands of the West Indies." *Trans. Can. Inst.*, vol. vii, pp. 351-370, 1901.

17-22. "On the Geological and Physical Development of:—Antigua; Guadeloup, Anguilla, St. Martin, etc.; St. Christopher Chain and Saba Banks; Dominica; with notes on southern

islands, Barbadoes and Trinidad." Six papers in *Quar. Jour. Geol. Soc., Lond.*, vol. lvii (1901), pp. 490-544 and vol. lviii, pp. 341-365. (The local development of the insular shelves, the submarine channels and valleys, and their associated geological and physiographic relationships are considered, while in No. 16 they are further correlated.)

23. "The Submarine Valleys Off the American Coast and in High Latitudes," *Bull. Geol. Soc. Am.*, vol. xiv, pp. 207-226, 1903. (This is an amplification of No. 7 and a delayed continuation of the paper on the Antillean Continent, No. 3.)

24. "The Submarine Great Canyon of the Hudson River," this *Journal*, IV, vol. xix, pp. 1-15, 1905. (The most perfectly explored of all the American canyons.)

25. "On the Physiographic Improbability of Land at the North Pole," as in this *Journal* preceding this list. (An application of the study of Submarine valleys to exploration of the unknown Arctic region.)

26. "Prof. Hull's 'Sub-oceanic Terraces and River-Valleys off the Coast of Europe.'" *A Review. Am. Geologist*, vol. xxxv, 13 pages (in press), 1905.

27. "Dr. Nansen's 'Bathymetrical Features of the North Polar Sea, with a Discussion of the Continental Shelves and the Previous Oscillations of the Shore-Line.'" *A Review. Am. Geologist*, vol. xxxv, 15 pages (in press), 1905. In this Dr. Nansen discusses American valleys.

The study of the submarine valleys is in its infancy, and while the work in the above papers somewhat overlaps and embraces many features, these have been considered incidental to working out the submarine channel, valleys, etc., dissecting the submarine border of the continent. These valleys are regarded of atmospheric origin from the facts brought out, therefore they become evidence of great changes of level of land and sea. Some of the consequences of such changes are considered. But only a commencement of the great problem has been inaugurated.

While references have been made to the work of others in the writer's papers, the addition of the following contributions will make a nearly complete list, so far as America is concerned. As to Europe, the references in the papers of Prof. Edward Hull and Dr. Fridtjof Nansen are equally comprehensive.

Prof. J. D. Dana: "The Hudson River Channel;" in all editions of *The Manual of Geology* (1863-1895).

"Long Island Sound in the Quaternary Era, with observations on the Submarine Hudson River;" this *Journal* (3), vol. xl, pp. 425-437, 1890. (In all cases the submarine channels are regarded as submerged valleys.)

Prof. A. Lindenkohl: "Geology of the Sea Bottom in the approaches to New York Bay," this *Journal* (3), vol. xxix, pp. 475-480, 1885.

"Notes on the Submarine Channel of the Hudson River, and other evidences of Postglacial Subsidence of the Middle Atlantic Coast Region. This Journal (3), vol. xli, pp. 489-499, 1891 (in which the channel was differentiated, with the recognition of the continuing canyon to a depth of about 3000 feet).

Prof. George Davidson: "Submarine Valleys of the Pacific Coast of the U. S." Bull. Cal. Acad. Sc., vol. ii, pp. 265-268, 1887. (Calling attention to the valleys and describing three of them, without discussion of origin.) Others are described in his Pilot of the Pacific Coast, 1889, pp. 35-36, 51-52. (He refers to having later designated them "submerged.")

"The Submerged Valleys off California (U. S.), and of Lower California (Mexico). Proc. Cal. Acad. Sc. (3), vol. i, pp. 73-103, 1897. (Here the Continental Shelf is considered, 31 submerged valleys are described dissecting it, and the features of the adjacent land are given. Several are traced to 2000 feet, one to 3600, and one to 5000 feet below the surface of the sea.)

Dr. Warren Upham: "Quaternary Changes of Level;" Geol. Mag. Lond. (3), vol. vii, pp. 492-497, 1890.

"The Fjords and Lake Basins of North America considered as evidence of Preglacial elevation, and depression during the Glacial Period." Bull. Geol. Soc. Am., vol. i, pp. 563-567, 1890. (He also treats of some foreign examples.)

"Submarine Valleys on Continental Slopes;" Abstract, Proc. Am. As. Ad. Sc., vol. xli, pp. 171-173, 1892.

"Fjords and Submerged Valleys of Europe;" Am. Geol., vol. xxii, pp. 101-108, 1898.

Prof. Joseph Le Conte: In Tertiary and Post Tertiary Changes of Atlantic and Pacific Coast," etc. Bull. Geol. Soc. Am., vol. ii, pp. 323-330, 1890. (Discusses the submerged valleys as such, with their beheading by orogenic movements.)

In "Earth-Crust Movements and their Causes;" Bull. Geol. Soc. Am., vol. viii, pp. 113-126, 1897. (He discusses the oscillations which favored the excavation of land valleys, and subsequently submerged them.)

Prof. A. C. Lawson: In "The Geology of Carmelo Bay;" Bull. Univ. Cal. (Geol. Dept.), vol. i, pp. 57-59, 1893, also page 155 (in which he briefly discusses the submarine valleys, believing them to be structural).

Prof. Harold W. Fairbanks: "Oscillations of the Coast of California during the Pliocene and Pleistocene." Am. Geol., vol. xx, pp. 213-245, 1897. (Discusses the submarine valleys, pp. 228-245, with the conclusion that they are submerged land valleys formed in the early Pleistocene days.)

Mr. W. S. Tangier Smith: "The Submarine Valleys off the California Coast," Science, vol. xv, pp. 670-672, 1902. (He suggests that some of the submarine valleys were made or opened by subterranean streams.)

Prof. N. S. Shaler: "Evidences as to the Changes of Sea Level." Bull. Geol. Soc. Am., vol. vi, pp. 141-166, 1895. (Discusses drowned harbors, that of St. Lawrence, etc., subterranean channels of Florida, etc.)

ART. XXXVI.—*On an Interesting Variety of Fetid Calcite and the Cause of its Odor*; by B. J. HARRINGTON.

ABOUT fifty years ago, when Sir W. E. Logan was studying the geology of the Grenville region in Canada, he came upon an interesting variety of calcite in the township of Chatham (lot 10, range xi) which emitted "when rubbed an overpowering odor like that of sulphuretted hydrogen."* In the "Geology of Canada," published in 1863, Dr. T. Sterry Hunt again called attention to what is evidently the same material, as follows: "We may here notice a peculiar variety of fetid carbonate of lime, which forms a large bed in the Laurentian series, in Grenville. It is a very coarse-grained, cleavable, milk-white and apparently pure calcite, which when struck or very lightly scratched, evolves a most powerful and unpleasant odor, recalling somewhat that of phosphuretted hydrogen. It dissolves without residue in dilute acids, and the carbonic acid gas evolved does not affect solutions of lead or silver salts, so that it is difficult to say to what the peculiar smell of this singular rock can be due. It is entirely distinct from the bituminous odor, which is evolved by percussion from a great many of the limestones of the Palæozoic series, or from that produced by striking some siliceous rocks."

Specimens of this interesting calcite have long been in possession of the writer, and it was felt that it should be possible to arrive at some definite conclusion with regard to the cause of the fetid smell. Thin sections were in the first instance studied and showed under the microscope the presence of great numbers of very minute cavities, evidently containing a liquid, as moving bubbles due to the contraction of the liquid could occasionally be seen. These cavities suggested the presence of hydrogen sulphide in a liquid condition or possibly in solution in water. If the gas were present in either condition, it was obvious that it would be liberated either by solution of the calcite in an acid or by pulverizing the mineral; further, that the finer the degree of pulverization the more hydrogen sulphide would escape. This was fully confirmed by experiments made both by the writer and by Mr. Lloyd Lodge, demonstrator in the chemical department. It has been found, moreover, that Hunt's observation with regard to the action of the escaping gas upon solutions of lead or silver salts is erroneous, for in both cases black precipitates are obtained, while in the case of cadmium salts the characteristic yellow precipitate is produced. The inference would appear to be

* Geological Survey of Canada, Report of Progress, 1858-54-55-56, p. 28.

that Hunt worked with the finely pulverized mineral, from which most of the hydrogen sulphide had been liberated, or that the gases were not passed into the solutions of the salts in question for a sufficient length of time.

A specimen of the calcite was found to have a specific gravity of 2.713 and gave on analysis the following percentage composition :

Lime	55.380
Magnesia.....	0.540
Ferric oxide	tr
Carbon dioxide.....	43.925
Sulphur as H_2S	0.016
Phosphoric anhydride.....	tr
Insoluble matter	0.026
	<hr/>
	99.837

The sulphur was determined by dissolving the mineral in dilute hydrochloric acid, passing the evolved gases into an alkaline solution of cadmium chloride and weighing the precipitate of cadmium sulphide. In the estimation of the phosphoric anhydride the mineral was dissolved in nitrohydrochloric acid, so that if any phosphorus were present as phosphide its oxidation to orthophosphate might be ensured. As the quantity of insoluble matter was insignificant, the determination was made upon about thirty grams of mineral—hydrochloric acid being the solvent. The filtrate from the insoluble matter was tested for sulphates, but gave no precipitate with barium chloride. In the analysis of another specimen of the calcite Mr. Lodge obtained results very similar to the above, but found a slightly higher percentage of hydrogen sulphide (0.021).

The following figures illustrate the different results obtained in determinations of the hydrogen sulphide according to the coarseness or fineness of the calcite :

	Lumps.	Powder of medium fineness.	Very fine powder.
H_2S from 29.45 } grams of mineral }	----		
	0.00471	0.00176	0.00035
Percentage of H_2S	0.01600	0.00560	0.00120

The figures show that the fine powder contained less than $\frac{1}{10}$ th of the amount present in the unpulverized material, and had the grinding been further prolonged there would no doubt have been a still greater difference.

On grinding a few fragments of the calcite under water in a porcelain mortar and filtering, the water contains sufficient hydrogen sulphide in solution to give the appropriate color

reactions with salts of silver, lead, cadmium, etc. If, again, the calcite be gently heated in a test-tube, hydrogen sulphide is liberated, and on heating somewhat more strongly the mineral generally decrepitates and gives off more hydrogen sulphide. On heating to 160° C. it shows a strong, deep yellow phosphorescence which persists for several minutes after removal from the source of heat.

From what has been stated it is evident that the hydrogen sulphide is the cause of the odor evolved when the calcite is scratched or rubbed, and although the quantity seems small when stated as percentage by weight it amounts to about 500 cubic inches of the gas per cubic foot of the mineral. Per cubic yard this would be about 13,500 cubic inches (a barrel and a half) of the gas, and the total quantity bottled up in the limestone of the region must be exceedingly large. It may exist in the calcite in a liquid condition, as in the case of the liquid carbon dioxide so frequently present in quartz, or in conjunction with water, or even with carbon dioxide. Mr. Douglas McIntosh, M.Sc., lecturer in chemistry, has kindly made some experiments for me which are interesting in this connection. He found that if solid carbon dioxide be dropped into liquid hydrogen sulphide and the tube sealed, as the temperature rises to that of the room the carbon dioxide dissolves and a homogeneous liquid is obtained, giving no evidence so far as appearance is concerned of the presence of two distinct compounds.

A small quantity of distilled water, again, was put into a tube and frozen, an equal volume of liquid hydrogen sulphide added and the tube sealed. When the ice melted, the two liquids could be seen to be separated by a distinct film—possibly of sulphur—which prevented their intermixing. In most cases when the tubes were heated they burst before the temperature reached 100° C. The same was also true if the tubes were inverted in position, that is with the water above the hydrogen sulphide; after standing for a short time the film gave way and the tube burst, possibly because of some sudden reaction between the two liquids. In one case, however, a tube which showed the distinct film separating the two liquids was forgotten and allowed to stand for some weeks. The film had then disappeared and, so far as one could tell by the eye, the two liquids had completely intermixed. On cooling the tube until the water crystallized out and then allowing it to gradually attain the temperature of the room, no separation of the two liquids took place. This would indicate that under the conditions of pressure in the tube, mutual solution of the water and hydrogen sulphide had taken place, and similar conditions may exist in the case of the fluid-cavities of the calcite.

Sir William Logan, judging from his description, regarded the fetid calcite as a local modification of one of the great bands of limestone belonging to the Grenville series. This modification might have been due to some form of solfataric action going on at the time of crystallization and introducing hydrogen sulphide, one of the usual accompaniments of such action. The crystals of pale green tourmaline (a boron mineral) which occasionally occur in the calcite might also point to solfataric action, though no such assumption is necessary to account for its presence. The hydrogen sulphide, again, might be taken as an indication of the existence of organic matter in the old sediments of the Laurentian series; for, as is well known, organic matter in presence of water reduces alkaline and earthy sulphates to sulphides, which reacting with water and carbon dioxide produce hydrogen sulphide. On the other hand, however, the hydrogen sulphide might have been produced from sulphides formed in the earth's crust quite independently of any organic agencies.

Associated with the fetid calcite there is also a white, translucent to subtranslucent quartz, which, on striking with a hammer or scratching with a knife, likewise evolves hydrogen sulphide. When fragments of the quartz are heated in a test-tube, considerable quantities of the gas are given off and readily darken lead acetate paper. No attempt has been made to estimate the proportion of the hydrogen sulphide in this case, nor does there seem to be any simple way of accomplishing this. In lump form the mineral would dissolve too slowly in hydrofluoric acid, while if powdered most of the hydrogen sulphide would escape. On heating the fragments, too, only a portion of the gas can be liberated and that in part at least is liable to undergo dissociation at the temperature of the experiment. The fluid-cavities in the quartz are, however, larger than in the calcite and more readily admit of study. Most of them afford no visible evidence of the presence of more than one liquid, and the moving bubble which they contain does not disappear on heating to 150°C —the highest temperature tried. In a few cases the bubbles disappeared at from 32° – 35°C ., indicating, no doubt, that the cavity contained liquid carbon dioxide whose critical temperature is 32°C . In one case the critical point was 40°C , and in several others from 60° – 65° , indicating, possibly, mixtures of carbon dioxide and hydrogen sulphide, the critical point of the latter being about 100°C . In cases where the bubbles did not disappear water is evidently present, accompanied no doubt by hydrogen sulphide and possibly by carbon dioxide as well. Some of the cavities, again, appear to contain two separate liquids with a bubble in one of them.

McGill University, Montreal.

ART. XXXVII.—*Alternations of Large and Small Coronas observed in Case of Identical Condensations produced in Dust-free Air saturated with Moisture,** by C. BARUS.

1. *Apparatus*.—By dust-free air, I mean air which has been passed through a packed cotter filter. My filters are 16 inches long, conical, tapering from about 2 inches in diameter at the large end to about one-half inch at the other. They contain absorbent cotton rammed in from both ends and kept in place by wire. When filtered air is required, the stop-cock is only just opened so that influx of dust-free air may be extremely slow. This insures proper filtration and does not interfere with the saturation of the air in the fog-chamber. In this paper condensation was produced in a long glass cylinder, 16 inches from end to end and $5\frac{1}{2}$ inches in diameter, placed horizontally and normal to the line of sight. It contained a rectangular framework of copper wire covered with wet cotton cloth, except on the two opposed broadsides through which the coronas were observed. The distance between the bottom (water) and the roof of the rectangular framework was about 9 centims. The provisions for keeping the air saturated are thus ample.

The vacuum chamber was a large boiler of galvanized iron, having a capacity V , of over $100,000^{\text{cub cm}}$, while the capacity v , of the condensation chamber is about $6,700^{\text{cub cm}}$, so that the volume ratio, v/V , is but .063. The two chambers are connected by about a foot of rubber tubing over one inch in bore, usually containing a one inch plug gas cock. An instantaneous clapper valve of the same dimensions and opened with a hammer was often used for comparison. Later the glass fog-chamber was advantageously replaced by one of waxed wood (cf. this Journal, xlix, p. 175, 1905), with the opposed sides, through which the coronas were observed, made of plate glass. The internal dimensions in this case were $55 \times 10 \times 20^{\text{cub cm}}$, and the volume ratio, v/V , in connection with the vacuum chamber about .13.

2. *Manipulation*.—The experiments were conducted as follows: Having selected a suitable pressure difference above that at which condensation in dust-free air just begins (usually termed the *fog-limit* in the present paper), the dust-free moist air in the closed condensation chamber at atmospheric pressure is suddenly exhausted and the corona measured. After all fog has subsided the exhaustion cock is closed and the filtered air very slowly admitted. The operations are then repeated allowing time (about 2-3 min.) for saturation. Under all circumstances the treatment for large and small coronas was identical.

In the given apparatus, condensation in dust-free moist air began at the pressure difference, $\delta p = 22.5$ for an atmosphere

* Read to the Am. Physical Soc., Feb. 25, 1905.

of 76^{cm} corresponding to the volume expansion of about 1.43. The pressure difference usually applied in the experiments was $\delta p = 31.2$, and the volume expansion 1.72.

3. *Alternation of large and small coronas (periodicity).*
Data.—The small coronas are usually sharp; but the large coronas appear blurred and filmy, accompanied with much rain. Remembering that all operations are conducted in a way strictly the same, the annexed figures 1 to 4 shows the coronas seen in the successive exhaustions. The angular diameter or aperture is $\sin \phi/2 = s/60$, or nearly $\phi = s/30$. The eye at the goniometer was about 40^{cm} from the axis of the condensation chamber (placed as close as possible to insure clearer vision) and the source of light 250^{cm} beyond it. Observations were made along the axis of the cylinder, placed horizontally.

In the case of 2 min. periods between the exhaustions (fig. 1) the periodicity is maintained without exception. For brevity let the smaller coronas be called inferior, the larger coronas superior. Frequently a very small inferior corona l evokes a relatively large superior corona h , or larger inferior coronas are followed by smaller superior coronas; but this is not always the case. As a more general rule, if the aperture is intermediate between the inferior and superior coronas, the succeeding corona is of the same size and oscillation terminates. Similar remarks may be made relative to the diagram, fig. 2, for 3^{m} periods between the exhaustions, or for fig. 4, for the case of dust-free air energized by weak radium ($10,000 \times$) in sealed glass tube.

4. *Remarks on the results.*—It will conduce to clearness to take the increase of apertures, s , with the increase of pressure difference, δp , first in order. If the exhaustion is insufficient, the groups of smaller nuclei will escape precipitation and the coronas be relatively small. After all nuclei, large and small, are caught, higher sudden exhaustion can no longer increase the apertures. More water is instantaneously precipitated per cubic centimeter. Nevertheless this counter-effect, if it is such, will also vanish with increasing pressure differences, because of the accentuated rapidity of thermal radiation. The adiabatic method ceases to be effective. Finally the necessity of producing sudden cooling simultaneously with extreme dilatation is a complication; for in view of the relative slowness of diffusion, it will eventually be impossible to keep the instantaneously dilated water vapor saturated, without arresting the growth of the fog particles. Above $\delta p = 40^{\text{cm}}$ the effect of sudden exhaustion may be conceived to actually dry the air, seeing that the density of vapor is instantly reduced more than one half, and hence even slight differences of supersaturation at the outset may show themselves effectively at these high exhaustions. Experimentally (figs. 6 and 7), these surmises are not fully

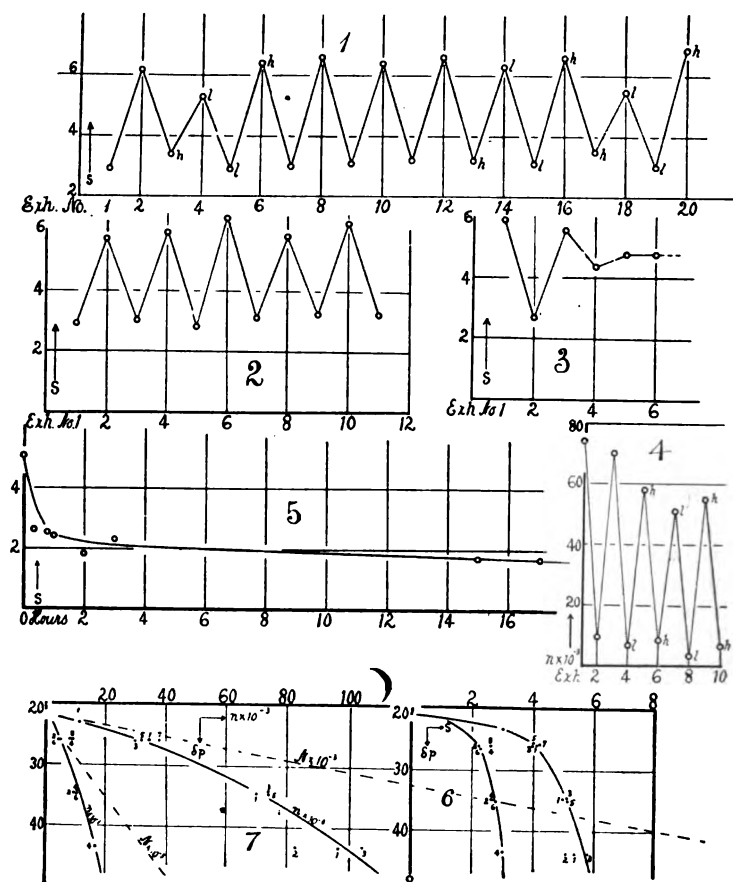
borne out: while the s -curves usually tend to reach an asymptote or a maximum, the N -curves (number of nuclei per cm^3 computed for normal pressure and temperature) do not usually do so, at least so far as observed in the case of non-energized air.

5. *Blurred coronas.*—The occurrence of an abundance of rain with all the coronas, as well as the blurred appearance of the coronas themselves, shows that gradation of particles is a characteristic feature with all these condensations. The following results for periodicity apparently indicate the presence of a group of markedly large particles in the amount of about $1/8$ or more of the total number of nuclei.

6. *Time loss of nuclei.*—In the lapse of time exceeding even half an hour (cf. fig. 5) the aperture of all coronas usually diminishes in marked degree. Above the fog-limit, however, the coronas do not vanish as the result of repeated exhaustion; i. e., the air can not be freed from nuclei by being stored in a closed vessel. What is particularly remarkable is the rapidity with which nuclei precipitated by condensation are again replaced. Whether these come through the filter in quasi-gaseous form, or whether they are spontaneously produced in the imprisoned air is yet to be decided. In every case something has to be explained away. If the nuclei came through the filter, for instance, they would not come periodically. If inferior coronas were due to undersaturation, superior coronas should be obtained in the lapse of time; the reverse of which is observed.

7. *Effect of pressure difference.*—With increasing pressure differences, δp , the superior and the inferior apertures each lie on distinct curves, as in figures 6 and 7, both of which rise rapidly at first, are then rapidly retarded and tend to reach distinct maxima. The limiting ratio of apertures is liable to be nearly one-half. If, however, the pressure difference is carried far enough, both s -curves sometimes change character by decreasing and increasing respectively, eventually to reach a common value. If then pressure difference is in turn reduced from these final values, the oscillation of s is usually absent and a mean nucleation appears at all subsequent (decreasing) pressure differences.

8. *Continued.*—The increase of nucleation, n , or N , with the pressure difference, δp , is often difficult to interpret, since the inferior and superior values are so much more widely and irregularly distributed. The n -curves usually show two limiting rates of increase of n with δp , respectively very large and very small. This is particularly well brought out in the data of figure 7 where both loci are nearly straight even above $\delta p = 40^{\text{cm}}$. Inferior coronas are sometimes absent and those observed present an accentuated case of superior corona; and vice versa.



LEGENDS FOR FIGURES.

CURVE 1.—Periodicity of dust-free air, showing the angular apertures of coronas (ordinates s) in successive identical exhaustions (numbered by abscissas), made at two-minute intervals apart. Note that high (h) inferior coronas are usually followed by low (l) superior coronas and vice versa; while high superior coronas are followed by high inferior coronas.

CURVE 2.—The same for three-minute periods between the exhaustions.

CURVE 3.—The same for five-minute periods. Periodicity gradually vanishes.

CURVE 4.—Periodicity of dust-free air energized by radium (10,000 \times) in glass, within the fog chamber. The successive exhaustions gradually reduce the nucleation. Sequences of h and l are apparent. The ordinates are number of nuclei per cm^3 . $\delta p = 25^{\text{cm}}$.

CURVE 5.—Dust-free air not energized, showing the reduction of nucleation (decreasing apertures, s) in the lapse of time.

CURVE 6.—Periodicity of apertures (s) at different pressure differences δp . The number of the exhaustions is attached to the observation. The loci of inferior and superior coronas are well marked.

CURVE 7.—The same computed for number of nuclei (N) in one cub. cm. of air at normal pressure.

9. *Fog-limits*.—An interesting feature of these results are the fog-limits or pressure differences at which condensation in dust-free air just commences. In spite of the different sizes of apparatus and valves used, the fog-limits are about the same, viz.:

$\delta p = 22-23$	Apparatus, wood, $v/V = .13$	Valve, plug.
21.5-	“ glass, $v/V = .06$	“ clapper.
22-23	“ “	“ plug.
21-23	“ “	“ clapper.
22-23	“ “	“ plug.

These results are surprising, inasmuch as the effect of the volume ratio of fog and vacuum chambers and the valve effect would naturally be looked to as productive of larger differences. With other apparatus (this Journal, vol. xix, p. 175) the data were

$\delta p = 22$	Apparatus, wood, $v/V = .7$	Valve, plug.
20	“ “ .7	“ clapper.

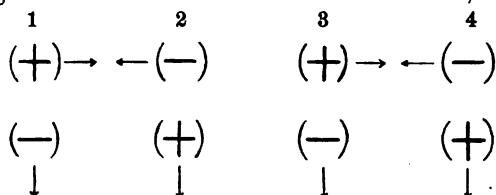
Thus the supreme importance of mere rate of exhaustion may well be called in question until more definite results appear; for with so large a difference of volume ratio v/V , of valve obstruction, etc., the essential features should appear more clearly. One may note that if colloidal molecules (extremely fine nuclei) pass through the filter, these would capture most of the moisture on condensation. It is possible therefore that if the filter is dispensed with and a closed vessel used, larger coronas will appear at smaller pressure differences for this reason.

10. *Alternations of large and small coronas*.—Effectively, the case of oscillation is one in which the large sparsely distributed fog particles emit more nuclei and the very abundant small fog particles fewer nuclei; i. e., the phenomena may be looked upon as though the nuclei were generated during the growth of the fog particles. This plausible explanation, however, is not easily maintained; for the emission would have to be as the growth of surface, in other words as the volume, and the number of particles varies inversely as their volume. A counter supposition may be hazarded to the effect that the fog particles of large coronas absorb more nuclei because of their abundance than the fog particles of small coronas. But the period of suspension of particles is too short to be of moment.

If negative ions are more active as condensation nuclei than positive ions, the results observed may be tentatively grouped in according with the following scheme (see diagram, p. 354).

Let the ions be originally neutral as a whole, and suppose, as in case 1, that the negative ions are first precipitated. In the interval between this and the next exhaustion fresh ions are generated or taken in through the filter, as shown in case 2. If these negative ions partially neutralize the positive ions left over in case 1, the second precipitation takes place on the

positive ions. Thereafter, case 3, the first is repeated, etc. But if the coronas are taken as a measure of the number of particles, the number of effective nuclei must be about eight times larger in the first case than in the second, whereas the



ions should be present in equal numbers. Hence there is serious objection to this hypothesis at the outset, quite apart from the numbers obtained, which are enormously too large.

11. *Undersaturation*.—Some mechanism of this kind is nevertheless probable, and it will work equally well if the undersaturation produced by the precipitation of fog particles is not rapidly made up by diffusion and convection. Of all hypotheses that of undersaturation has the broadest bearing and accounts qualitatively for most of the phenomena, as will presently be pointed out in detail. True, the large coronas must be supposed to carry down more moisture than the small coronas, but the difference need not be great. The hypothesis encounters a serious obstacle inasmuch as the coronas obtained from saturated air which has been imprisoned for long intervals of time (§ 8), are usually an extremely small type of inferior corona, whereas they should be large superior coronas. Long intervals of waiting between exhaustions brings out not a superior corona but at best one of intermediate size. Another precarious feature is suggested by computing the rate at which saturation should be established in the most unfavorable case of the middle air layer, between the wet top and bottom of the fog chamber, for diffusion alone.

In fact if diffusion takes place from the wet top and bottom of the rectangular trough of height a , into a partially saturated atmosphere of initial vapor pressure p_0 , then at any time t , at the middle plate $x = a/2$

$$p = 1 + \frac{4(p_0 - 1)}{\pi} \left(\sin \frac{\pi}{2} \epsilon^{-(\pi/a)^2 kt} + \frac{1}{3} \sin \frac{3\pi}{2} \epsilon^{-(3\pi/a)^2 kt} + \text{etc.} \right)$$

where $dp/dt = k (d^2 p/dx^2)$. Hence if $a = 11^{\text{cm}}$ as in the largest trough (wood), and if $k = .23$, the following values obtain.

$t = 30$	$p_0 = 0, p = .28$	$p_0 = 1/3, p = .52$	$p_0 = 2/3, p = .76$
60	.59	.72	.86
120	.87	.91	.96
180	.96	.97	.99

In the above tables a was usually less than 10^{cm} (glass fog chamber), making the condition correspondingly favorable.

Hence by diffusion alone there should be saturation after two to three minutes even at the most distant (middle, $x = a/2$) plane, to within a few per cent; for the central layer is probably always more than half saturated at the outset. In addition to diffusion, however, there is marked convection due to the lightness of water vapor. At the same time there is no evidence that the more numerous but small drops of the superior coronas carry down a sufficient excess of water; nor are the coronas, though blurred otherwise distorted, as they would be for a definite diffusion gradient.

12. *Continued.*—Assuming however that undersaturation does occur and is oscillatory as the result of successive larger and smaller precipitations, the cases may be interpreted in succession as follows;

a. The superior coronas carry down more moisture and should apparently be followed by even larger coronas; and vice versa: but after the fog particles producing the superior coronas are precipitated, the supersaturation possible for the given pressure difference applied no longer catches the small nuclei. Hence the inferior coronas appears in succession. Hence also, apart from what may be time errors in opening the stopcock, very large pressure differences tend to wipe out the oscillation as all the nuclei are captured.

b. The ratio of 1:2 for coronal apertures and of 1:8 for the numbers of fog particles seems out of keeping with the slight differences of supersaturation instanced in 13; but this is again a question of catching the smaller nuclei as a group.

c. The phenomenon is much too definite an oscillation of aperture between s and $2s$ (nearly) to be referable to an irregular cause like deficient supersaturation; but the two types of nuclei admit of a wide range of saturation, as long as there is a correspondingly wide difference in the sizes of nuclei.

d. A series of minor observations are favorable to the hypothesis of residual undersaturation; as for instance, the eventual coalescence of the aperture curves of the superior and the inferior coronas; the dew effect; the fog effect and shaking; the fact that very small inferior coronas are followed (caet. par.) by large superior coronas while the latter are followed by large inferior coronas, etc.

e. Finally, while superior coronas are followed by inferior coronas and vice versa, mean coronas follow each other.*

13. The values of the nucleation (number of nuclei per cub. cm.) of the inferior and the superior coronas naturally

* I have since proved that periodicity is due to the formation of water nuclei by evaporation. On these the inferior coronas condense. Points a to e then follow. The ions become solutes.

present a more striking contrast, since the third power of aperture is involved. Otherwise but few new results are to be inferred from them. If the long series of figure 1 be taken, which contains the data of twenty successive alternations, the average inferior nucleations are 11,800, and the average superior nucleations 94,000, supposing, of course, that the precipitated water is the same in both cases and that it is all condensed on the available nuclei. In other words, if the two cases are otherwise identical, the superior coronas correspond to a number of nuclei eight times greater (frequently larger than this in the other observations) than the inferior coronas. As this explanation is the more probable, it follows that the nuclei (as stated in §10) cannot be regarded as positive and negative ions. They are rather the groups of large and small nuclei seen throughout the condensations in connection with the rain and the blurred coronas. Apart from this the numbers obtained throughout are quite out of keeping with any similarly observed ionization. If, however, free electrons appear only at the destruction or at the origin of nuclei, the association of few ions with many nuclei at any time subsequent to their origin, is well accounted for, as already suggested in the earlier paper. It is only while the nuclei are being produced that the ionization and the nucleation must be of the same order; for the latter persists while the former vanishes at once. Finally the following results are implied at least for the physical structure of air saturated with water vapor:

Air (dust-free) is inseparably intermixed with large and small nuclei, whose number (to be reckoned in millions per cubic centim.) rapidly increases as the order of molecular size is approached. There seems to be no objection to looking upon these nuclei as a kind of colloidal (air) molecule, particularly as such molecules are frequently producible by the means (Bredig) which produce nuclei. If a large number of free atoms is suddenly introduced into any region (and this is probably what the radiation of the above kind virtually does), the result is not merely a production of typical molecules but of a large concomitant of graded nuclei.

Practically any given nuclear status of air is a counterpart of the intensity of the ionization of the medium in which the nucleation originated, to the effect that the superior limit of size of the nuclei and their number increase with the ionization. But there is no case of ionization free from nucleation, be the exciting cause a mere radiation as above, or ignition, combustion (including the low temperature cases like phosphorus), or high potential discharge, or violent comminution as in the case of water nuclei,—the two manifestations being often distinguishable by enormously different rates of decay.

Brown University, Providence, R. I.

ART. XXXVIII.—*New Circular Projection of the Whole Earth's Surface*; by ALPHONS J. VAN DER GRINTEN, Chicago.

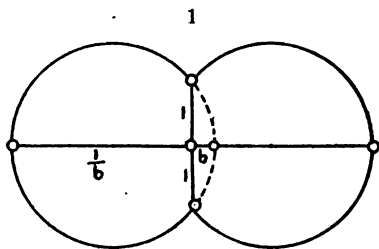
THE representation of the surface of a sphere upon a plane is a problem which has occupied the attention of cartographers for centuries. The problem has been solved in many ways, but always at some sacrifice of form or relation of parts, depending upon the requirements of conformity or equivalence.

Conformal projections necessarily exaggerate the areas toward the margin (Eisenlohr, August, et al.), while the equivalent ones (Werner, Mollweide, Sanson) reduce the angles formed by the intersection of parallels and meridians considerably. Each of these devices introduces such errors of representation that a comparison of areas and places in the different parts of the globe becomes rather difficult. A third principle, introduced in an attempt to distribute these errors over the map, also fails to obtain the most favorable result, an increase of distortion in tropical latitudes hardly being offset by an increase in accuracy in the less important polar regions.

These conditions, therefore, make desirable a new method of projection, by which all the deformations shall increase regularly from a zero value at the equator to the least possible maxima at the poles. The network may be formed exclusively by straight lines and circular arcs, as the polar flattening can be neglected as unimportant in a map of so small a scale as is required to represent the whole earth's surface.

The device of using circular arcs for parallels and meridians results in the production of an apple-shaped marginal meridian, having the central meridian and the equator as straight lines.

If b represents the ratio of the lengths of these main lines of the projection, a mathematical investigation shows that the most favorable expression of the total deformation, dependent upon the elements h , k and Θ , as will be shown later, is obtained when the two circles, the marginal meridians of the two hemispheres,



cover each other, so fusing into one true circle: $b = 1$. The mathematical deduction as given here, for this case, is based upon Tissot's theories of deformation, as given in his famous "*Mémoire sur la représentation des surfaces et les projections des cartes géographiques*"

(1881), augmented by E. Hammer in "Die Netzentwürfe geogr. Karten, von A. Tissot, 1887."

J. H. Lambert (1772) was the first to recognize the circular form as the most natural one for the representation of the whole globular surface, but failed to notice the fact that his conformal projection would admit of a simple geometrical construction. Even the most modern treatises on projections reprint his table containing the numerical values of the distances d and s of the parallels and their centers from the equator. Recently Zöppritz, Reclus and others have urgently recommended the circular form of representation, not only for the whole earth, but for parts of it as of the continents. Although Lambert's projection must be considered as a theoretical "Unicum" its insufficiency for practical purposes becomes evident, in the stereographic arrangement of the

meridians, and the subsequent primary subdivision ($c = \tan \frac{\phi}{2}$) of the central meridian, reducing too much the central parts of the map as compared with those near the margin.

In order to remedy this defect, I am proposing a projection in which the meridians intersect the equator at equal distances, and then the distances and curvatures of the parallels are altered in such a way that no alteration whatever occurs along the equator. Then we readily obtain our distance d , by substituting $c = \frac{\phi}{90}$ for $c = \tan \frac{\phi}{2}$ in Lambert's formula

$$d = \frac{\sqrt{1 + \tan \frac{\phi}{2}} - \sqrt{1 - \tan \frac{\phi}{2}}}{\sqrt{1 + \tan \frac{\phi}{2}} + \sqrt{1 - \tan \frac{\phi}{2}}} \text{ thus :}$$

$$d = \frac{\sqrt{1+c} - \sqrt{1-c}}{\sqrt{1+c} + \sqrt{1-c}} = \frac{1 - \sqrt{1-c^2}}{c} = \frac{\sqrt{90+\phi} - \sqrt{90-\phi}}{\sqrt{90+\phi} + \sqrt{90-\phi}},$$

which can just as easily be constructed geometrically (see figure 2) as that of Lambert.

It now remains to determine the distance from the equator (y) of the intersecting point of any parallel and any marginal meridian, in such a manner that the distortion of angle ($\Theta = 90 - \eta$) formed by them be a minimum; inasmuch as the requirement of a minimum 2ω would necessitate a maximal Θ between the equator and the poles, as will be explained later in this paper.

y can be determined in different ways. If a rectangular network is proposed ($\Theta = 0$), we find $y = c = \frac{\phi}{90}$; if the paral-

les are to run as straight lines parallel with the equator, we have $y = d$, in which case, although equivalence and conformity are preserved along the equator, Θ increases to 90° at the poles ($\eta = 0$); and finally if it is required that the deformation (κ) of any parallel at the marginal meridian shall be equal to its deformation at the central meridian, in which case all the parallels are practically intersected by the meridians at equal distances, we get

$$y = d \frac{3-d^2}{2}.$$

By the first arrangement (rectangular trajectories) the parallels at the margin would approach too near to the poles (h representing the deformation of meridional parts, ϕ the latitude, and λ the longitude):

$$h_{\lambda=180}^{\phi=0} = 2; \quad h_{\lambda=180}^{\phi=90} = h_{\lambda=0}^{\phi=90};$$

in the second case they would appear to be too far distant from the poles:

$$h_{\lambda=180}^{\phi=90} = \infty \cdot h_{\lambda=0}^{\phi=90};$$

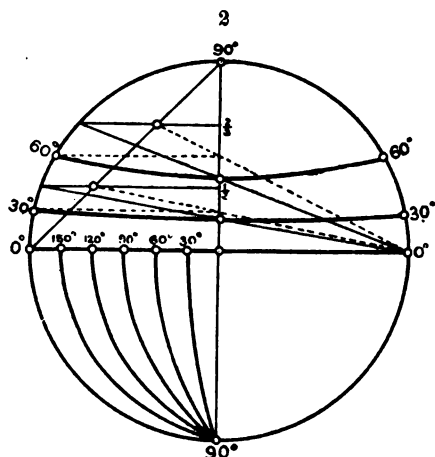
finally in the third case we are confronted with an unhappy congestion of the temperate zones:

$$h_{\lambda=180}^{\phi=0} = \frac{2}{3}; \quad h_{\lambda=180}^{\phi=90} = \sqrt{3} \cdot h_{\lambda=0}^{\phi=90}.$$

Therefore it seems desirable to find a middle ground by having all alterations continuously increased from zero at the equator to their least maxima at the poles:

$$h_{\lambda=180}^{\phi=0} = 1; \quad h_{\lambda=180}^{\phi=90} = \sqrt{2} \cdot h_{\lambda=0}^{\phi=90}.$$

This arrangement has the effect of making the continental regions fall within the zone of least "total error," though this

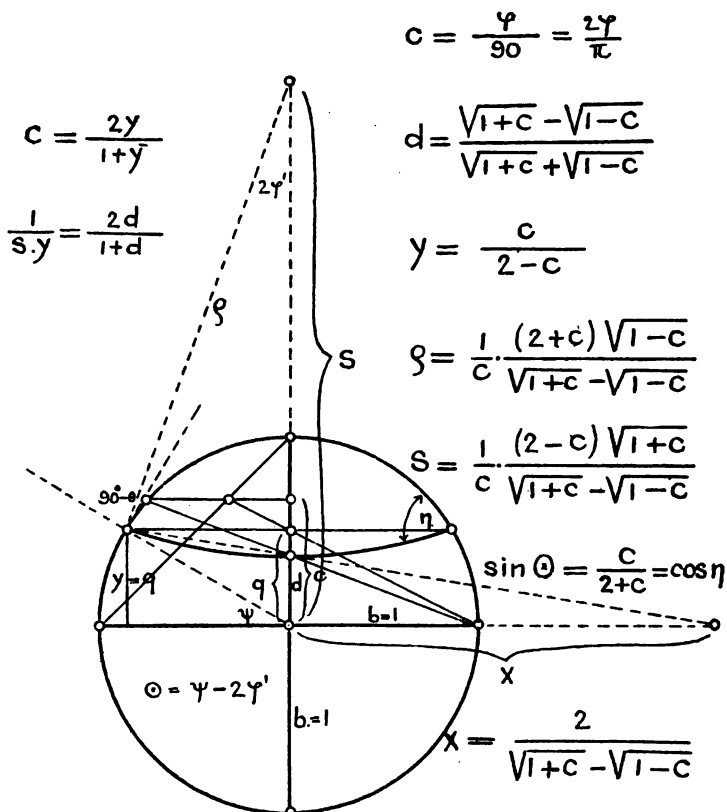


GEOMETRICAL CONSTRUCTION

Patented in U.S., Canada, Gr. Britain & France,

term must be used with reserve as no exact definition of it can be given; linear, angular, and areal values being of a heterogeneous character. Here it is the simplicity of the formula or construction which proves its superiority in the solution of an intricate problem.

3



The formula for our y can easily be developed by the following reasoning (fig. 3). The proportion

$$\frac{x}{x + \sqrt{1-y^2}} = \frac{d}{y} \text{ gives } y = d \frac{x^2 + \sqrt{x^2(1-d^2) + d^2}}{x^2 + d^2}.$$

Now in order to preserve conformity and equivalence along the equator (the meridians here being equidistant) we can substitute for x the arbitrary value $\frac{a}{d}$, which is to be so deter-

mined, that y comes nearest to $c = \frac{\phi}{90}$ for rectangular projection, making Θ , continuously increasing, a minimum. The above expression then is

$$y = d \frac{a^2 + d\sqrt{a^2(1-d^2) + d^2}}{a^2 + d^2}; \text{ and as } \sqrt{a^2(1-d^2) + d^2}$$

cannot exceed the unit ($d = 1$; $y = 1$), y will become a maximum, under the limitation $x^\phi = 0 = \infty$, and, therefore, Θ a minimum, just when $\sqrt{a^2(1-d^2) + d^2}$ is made a unit, giving

$$a = \sqrt{1+d^2}, \text{ or } x = \frac{\sqrt{1+d^2}}{d}, \text{ and finally } y = \frac{d}{1-d+d^2} = \frac{c}{2-c}$$

$$\text{and } \sin \theta = \sin (\psi - 2\phi') = \frac{d}{1+d+d^2} = \frac{c}{2+c}. \text{ Any other value}$$

for a , less than $\sqrt{1+d^2}$, would produce a maximum of Θ between the equator and the poles. This maximum would reach its climax for $a = 1$, $x = \frac{1}{d}$ ($\Theta = 0$ at the equator and at the poles), the determination and location of which would require the solution of a very lengthy equation. The requirement of a minimal 2ω involves a much more intricate equation still for the determination and location of the maximal Θ that is formed between the equator and the poles.

The harmonic relation between y , c and the radius of the marginal meridian (= unity) is then defined by $c = \frac{2y}{1+y}$.

Other harmonic relations occur at latitudes 72° and 54° as $y = \frac{2d}{1+d^2}$ and $y = \frac{2cd}{c+d}$ respectively.

I now offer the formulas of deformation in the most condensed form, which will furnish the necessary data for a table showing the most characteristic features of the circular projection in a numerical way; and which will enable the student of cartography to extend the table to apply to any interval of latitude whatsoever.

Deformation.

The deformation of an infinitely small part of the central meridian at a point $\left(\frac{\phi}{\lambda}\right)$ is expressed by the ratio $h_{\lambda=0} = \frac{\delta d}{r \delta \phi}$, r representing the radius of any globe. It being necessary to have $h_{\lambda=0} = k_{\lambda=0} = 1$ at the center of the map, we get

$$r = \frac{\delta d}{\delta \phi_0}, h_{\lambda=0} = \frac{\frac{\delta d}{\delta \phi}}{\frac{\delta \phi}{\delta \phi_0}}$$

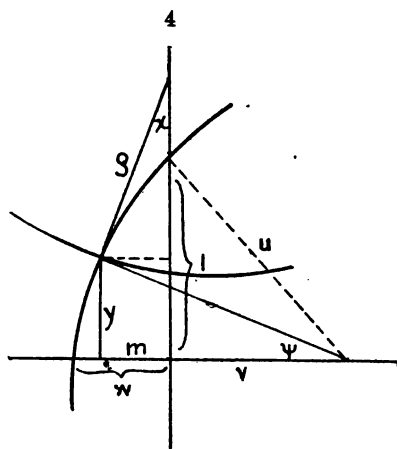
consequently (I) $h_{\lambda=0} = \frac{2}{c} \cdot \frac{\sqrt{1+c} - \sqrt{1-c}}{(1+c)\sqrt{1-c} + (1-c)\sqrt{1+c}}$.

The deformation of an infinitely small meridional part at the margin is defined by $h_{\lambda=180} = \frac{\delta \psi}{r \delta \phi}$. Now having $\sin \psi = y$, we finally get

$$(A) h_{\lambda=180} = \frac{y}{d} \cdot \frac{\sqrt{1-y^2}}{1-dy} \cdot h_{\lambda=0},$$

and in our case

$$(II) h_{\lambda=180} = \frac{4}{(2-c)[(1+c)\sqrt{1-c} + (1-c)\sqrt{1+c}]} = x \cdot y \cdot h_{\lambda=0}.$$



The deformation of a part of a parallel between two infinitely approximate meridians is explained by

$$k = \frac{\rho \delta x}{r \cos \phi \delta \phi} = \frac{\rho}{r \cos \phi} \cdot \frac{\delta(2\phi')}{\delta \phi},$$

from which is obtained the general formula

$$k = \frac{1}{r} \left(\frac{\delta u}{\delta \lambda} - \frac{\delta v}{\delta \lambda} \cos \psi \right) \cdot \frac{\frac{\delta w}{\delta \lambda}}{\cos \phi \cos \theta}$$

wherein u denotes the radius of any meridian, v the distance of its center from the central meridian and w the linear longitude. There we have $v = \frac{1-w^2}{2w}$; $u = \frac{1+w^2}{2w}$ and $\frac{\delta v}{\delta \lambda} = -\frac{1+w^2}{2w^2} \cdot \frac{\delta w}{\delta \lambda}$; $\frac{\delta u}{\delta \lambda} = -\frac{1-w^2}{2w^2} \cdot \frac{\delta w}{\delta \lambda}$ and substituting $k = \left(\frac{m}{w}\right) \frac{1}{\cos \phi}$, where $\left(\frac{m}{w}\right)$ becomes indefinite $= \frac{0}{0}$ at the central meridian, and find: $\left(\frac{m}{w}\right) = 1-d^2$; $k_{\lambda=0} = \frac{1-d^2}{\cos \phi}$ or finally,

$$(III) \quad k_{\lambda=0} = \frac{2}{c} \cdot \frac{(1+c)\sqrt{1-c} - (1-c)\sqrt{1+c}}{\sqrt{1+c} + \sqrt{1-c}} \sec \phi.$$

For the deformation k at the marginal meridian we get by the above general formula: $k_{\lambda=180} = \frac{\cos \psi}{\cos \phi \cos \theta}$, from which we derive: by (B) $\sin \theta = \frac{2d-y(1+d^2)}{1-d(2y-d)} = \frac{c-y}{1-cy}$ the general expression: (C) $k_{\lambda=180} = \frac{1-d(2y-d)}{(1-d^2)^2} \cdot k_{\lambda=0}$ and for our $y = \frac{c}{2-c}$:

$$(IV) \quad k_{\lambda=180} = \frac{(2+c)\sqrt{1-c}}{(2-c)\sqrt{1+c}} \sec \phi = \frac{\rho}{s} \sec \phi.$$

The deformation of area at the central and marginal meridians is defined by

$S_{\lambda=0} = h_{\lambda=0} \cdot k_{\lambda=0}$ and $S_{\lambda=180} = h_{\lambda=180} \cdot k_{\lambda=180} \cdot \cos \theta$, respectively.

The maximal and minimal linear alterations are then represented by the conjugate diameters a and b of an infinitely small ellipse—called the indicatrix—which is produced by an orthogonal projection of an infinitely small circle—circumscribing a point $\left(\frac{\phi}{\lambda}\right)$ —from any curved surface upon a plane.

These diameters are defined by the relations:

$$\begin{aligned} a^2 + b^2 &= h^2 + k^2 \\ a \cdot b &= s = h \cdot k \cdot \cos \theta \end{aligned}$$

and the maximal distortion of angle (2ω) by

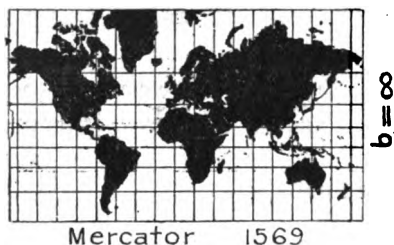
$$\sin \omega = \frac{a-b}{a+b} = \sqrt{\frac{h^2 + k^2 - 2hk \cos \theta}{h^2 + k^2 + 2hk \cos \theta}}.$$

The $y = d \frac{3-d^2}{2}$ projection coincides with ours for $d = \frac{\sqrt{5}-1}{2}$;

$\theta = 18^\circ$; $\phi = 80^\circ$, 46 (sectio divina).

A minimum 2ω value coincides with our minimum θ in a lati-

5



tude, where we have to surmount the difficulty of fairly representing the most northern parts of the continents of America and Asia ($\phi = 68^\circ$ rot., see table).

Our circular representation can also be considered as a transformation of the two hemispheres into the most natural planisphere, the circumference of which is equal to the circumferences of the two hemispheres combined, so that we always have the superficial area of a globe of half the diameter before our view.

Fig. 5 will serve to compare same with those of Mercator and Mollweide, of which the latter has recently been supplanted by the Aitoff-Hammer "equivalent" projection showing a little improvement in regard to the distortion of angle, leaving it, however, useless for the representation of polar exploration like that of Mercator's "conformal" with the distortion in the opposite

direction. Furthermore, Mercator's design was not intended for geographical, but merely for maritime purposes, the loxodromic line appearing as a straight line :

"Nova et aucta orbis terrae descriptio ad usum navigantium emendate accomodata."

6



CONTINENTAL VIEW



AMERICAN VIEW

II.

TABLE OF APPROXIMATE VALUES OF DEFORMATIONS.

y	h	k	Θ	2ω	$S_{\lambda=180}$	$\frac{S_{\lambda=180}}{S_{\lambda=0}}$
<div>Equator</div> <div>$\phi=0^\circ$ $\lambda=0^\circ$</div>						
	1,000	1,000	0° 0'	0° 0'	1,000	
$\lambda=180^\circ$						
$y = \begin{cases} d=0,000 \\ c=0,000 \end{cases}$	1,000	1,000	0° 0'	0° 0'	1,000	1,000
$y = \begin{cases} c=0,000 \\ 2-c=0,000 \end{cases}$	1,000	1,000	0° 0'	0° 0'	1,000	1,000
$y = \begin{cases} d=0,000 \\ c=0,000 \end{cases}$	2,000	1,000	0° 0'	38° 56'	2,000	2,000
<div>Arctic and Antarctic Circles</div> <div>$\phi=66^\circ 33'$ $\lambda=0^\circ$</div>						
	1,768	2,025	0° 0'	7° 22'	3,580	
$\lambda=180^\circ$						
$y = \begin{cases} d=0,441 \\ c=0,586 \end{cases}$	1,969	2,513	26° 6'	30° 22'	4,443	1,241
$y = \begin{cases} c=0,586 \\ 2-c=0,586 \end{cases}$	2,568	2,116	15° 40'	19° 20'	5,233	1,462
$y = \begin{cases} d=0,441 \\ c=0,739 \end{cases}$	2,967	1,693	0° 0'	81° 42'	5,023	1,403
<div>Minimum 2ω</div> <div>$\phi=68^\circ$ $\lambda=0^\circ$</div>						
	1,853	2,109	0° 0'	7° 40'	3,908	
$\lambda=180^\circ$						
$y = \begin{cases} d=0,458 \\ c=0,607 \end{cases}$	2,084	2,670	27° 15'	31° 40'	4,947	1,266
$y = \begin{cases} c=0,607 \\ 2-c=0,607 \end{cases}$	2,704	2,208	15° 45'	19° 48'	5,743	1,469
$y = \begin{cases} d=0,458 \\ c=0,756 \end{cases}$	3,058	1,745	0° 0'	31° 40'	5,336	1,365
<div>Harmonical Relations</div> <div>$\phi=72^\circ$ $\lambda=0^\circ$</div>						
	2,083	2,427	0° 0'	8° 44'	5,056	
$\lambda=180^\circ$						
$y = \begin{cases} d=\frac{1}{2} \\ c=\frac{1}{2} \end{cases}$	2,406	3,236	30° 0'	35° 32'	7,786	1,540
$y = \begin{cases} c=\frac{1}{2} \\ 2-c=\frac{1}{2} \end{cases}$	3,208	2,517	16° 39'	20° 40'	7,414	1,466
$y = \begin{cases} d=\frac{1}{2} \\ c=\frac{1}{2} \end{cases}$	3,333	1,942	0° 0'	30° 36'	6,473	1,282
<div>Poles</div> <div>$\phi=90^\circ$ $\lambda=0^\circ$</div>						
	∞	∞	0° 0'	13° 35'	∞	
$\lambda=180^\circ$						
$y = \begin{cases} d=1,000 \\ c=1,000 \end{cases}$	∞	∞	90° 0'	180° 0'	∞	∞
$y = \begin{cases} c=1,000 \\ 2-c=1,000 \end{cases}$	∞	∞	19° 28'	30° 0'	∞	1,000
$y = \begin{cases} d=1,000 \\ c=1,000 \end{cases}$	∞	∞	0° 0'	25° 38'	∞	0.500

ART. XXXIX.—*On the Progress of the Albatross Expedition to the Eastern Pacific*; by ALEXANDER AGASSIZ.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Acapulco, Mexico, February 24, 1905.]

WE left the Galapagos (Wreck Bay) for Manga Reva on the 10th of January. On the northern part of this line we did but little work beyond sounding as we were likely to duplicate our former work to the eastward. The fourth day out, in latitude 5° south, we began a series of trawl hauls, surface hauls, and intermediate towings to 300 fathoms. In the northern part of the line to Manga Reva the hauls were remarkably rich as long as we remained within the influence of the western extension of the Humboldt Current, and as long as there dropped from the surface masses of the radiolarians, diatoms and Globigerinæ living in the upper waters. Some of the hauls were remarkable for the number of deep-sea holothurians and siliceous sponges. Among the former I may mention a huge *Psychropotes*, 55^{cm} long.

As we passed south and gradually drew out of the influence of the western current, we entered the same barren region we passed through to the eastward when going to and from Easter Island. By the time we reached latitude 15° S., the hauls became quite poor; this barren bottom district extended to within a short distance of Manga Reva; corresponding to it we found a most meager pelagic fauna, both at the surface and down to 300 fathoms—so poor that it could afford but little food to the few species, if any, living on the bottom in that region.

We arrived at Manga Reva on the 27th of January and found our collier awaiting our arrival.

While at anchor in Port Rikitea, we examined Manga Reva, the principal island of the Gambier group, from its central ridge on the pass leading from Rikitea to Kirimiro on the west side of Manga Reva, as well as from the pass leading to Taku. On both these passes we obtained excellent views of the barrier reef to the west, north and east of the Gambier Islands, and we could trace in the panorama before us the western reef extending in a northeasterly direction parallel to the general trend of Manga Reva Island for a distance of about $5\frac{1}{2}$ miles.

From the northern horn to nearly opposite Kirimiro Bay the barrier reef has only three small islets; it is narrow, of uniform width, about $\frac{1}{8}$ of a mile, plainly defined, submerged in places, and passing north bounds a large northern bight dotted with numerous interior coral patches from a quarter of

a mile to a mile in diameter or length, with from 7 to 11 fathoms. The southern part of the western barrier lagoon off Manga Reva is irregularly dotted with many small patches of reef, with an occasional deep hole of from 15 to 20 fathoms near Manga Reva Island. From the islet to the west of Kirimiro there are but few coral patches, indicating a reef which dips gradually in a distance of a mile to a deep channel of from 4 to 6 fathoms, which separates the northern and western reef from the great reef flat lying to the southwest of Tara Vai. This flat has a width of nearly 2 miles, is about $4\frac{1}{2}$ miles long, and is marked at its southwest extremity by a series of low islets arranged in a somewhat circular line, formed by three deep bays and spurs from the outer line of islets, as so frequently occurs on a wide reef flat in atolls of the Pacific.

This part of the reef is called Tokorua. It shelves very gradually from $3\frac{1}{2}$ to 4 fathoms on the west face to 7, and connects with the plateau upon which stands Tara Vai and Agakanitai. From Tokorua the reef extends in an indefinite narrow ridge 8 miles long, with from 3 to 8 fathoms, in a southeasterly direction. The western edge is steep to, and the eastern face passes gradually into the lagoon, which at that point has a general depth of 8 to 20 fathoms. The deepest part of this region is at the foot of Mt. Mokoto between it and Tara Vai, though Tara Vai is united with Manga Reva Island by a plateau varying in depth from $3\frac{1}{2}$ to $4\frac{1}{2}$ fathoms.

At the southeastern point of the reef it passes into a wide plateau with from 9 to 10 or 15 fathoms. This plateau is about 9 miles wide southwest of Tekava. That part of the atoll has not been well surveyed, so that the position of the reef flat has not been ascertained further west on that part of the east face; but the southeast passage indicates $5\frac{1}{2}$, 6 and $6\frac{1}{2}$ fathoms, where it probably marks the southwestern extension of the eastern barrier reef, separating the lagoon from the southern plateau to the south of the encircling reef.

The western face of Manga Reva and of Tara Vai are indented by deep bays, which are formed by spurs running from the central ridge of these islands, the remnants probably of small craters which flanked the large crater, of which Manga Reva forms the western rim and Au Kena is the remnant of the southeastern edge, the former extension of this rim being indicated by the spits uniting the base of Mt. Duff with Au Kena; and by the projection of Au Kena towards the outer barrier reef, and of the numerous patches of coral reef off the northeast point of Manga Reva towards the outer line of motus until they almost unite with the barrier reef.

The western bays of Manga Reva Island are filled with fringing reefs which leave but here and there a deeper pass to the shore. The south face at the foot of the bluff of Mt. Mokoto and Mt. Duff is edged by a flourishing fringing reef, which extends nearly half a mile on the plateau at their base. The port of Rikitea is a reef harbor formed within the large fringing reef which occupies the whole of the southern bay of Manga Reva Island. The east face of Tara Vai and part of the east and of the west face of Aga-kanitai are also fringed with reefs.

The islets and the islands of Aka Maru, Mekiro, and Maka-pu are within a fringing reef flat which runs around the west face of Aka Maru; Au Kena is also fringed by an extensive reef which runs out in a spit of more than half a mile in a north-easterly direction almost to the outer line of motus, which are nearly united with it by these irregular patches. To the west of Au Kena a huge spit of 2 miles in length extends towards the base of Mt. Duff and almost unites with the fringing reef off the Cemetery, leaving a narrow but deep pass for the entrance of ships into the inner harbor of Rikitea. There is only 1 to 2½ fathoms of water on these two spits.

The depth of the basin within this area with from 25 to 31 fathoms would be naturally explained as being part of an ancient crater, as in Totoya in Fiji; its northeastern rim is also perhaps further indicated by the comparatively shallow flat of the lagoon to the west of the barrier reef, with from 5 to 11 fathoms of water.

The principal islands of the group are in the central part of the lagoon. The four larger islands are Manga Reva, Tara Vai, Au Kena and Aka Maru. Tara Vai is flanked by Aga-kanitai and another islet to the west called Topunui; Aka Maru is flanked by Mekiro to the north and by Maka-pu to the south. The southeast face of Aka Maru is an extinct crater, of which Maka-pu forms the south rim. The main ridge of Tara Vai is the edge of parts of three craters now opening to the west. The four small volcanic islands in the southern part of the lagoon are isolated fragments, steep to, greatly weathered, and disintegrated. No soundings exist to show their relation to the other islands of the group.

The soundings thus far made indicate in the southern part of the lagoon a depth of about 23 fathoms, with an occasional hole of from 38 to 40, and a gradual slope towards the outer sunken reef. To the south of the old crater of Manga Reva the general depth of the bank varies from 6 to 11 fathoms, with a deeper channel varying from 20 to 40 from southwest of Au Kena towards Tara Vai. The lagoon seems to form a western basin where the depth varies from 10 to 20 fathoms.

To the west of Au Kena and Aka Maru, lying between them and the line of the outer barrier reef islets, a similar but shallower and flat basin exists, off the northern end of Manga Reva, between it and the northern horn of the barrier reef, with from 7 to 11 fathoms. Its rim is formed by a ring of reef patches of varying size.

On two occasions we visited the outer barrier reef and examined the outer line of islets of the eastern face of the Gambier Islands. The position of the islets as marked on the chart is not that of to-day, and the position of the reef flats is not accurate. The position of Tekava and Tauna appears to be correct. Opposite Au Kena and in its extension, the east face of the barrier reefs projects sharply to the east, forming an angular horn with one island south of the horn and the other north, running at sharp angles with it, so as to form a triangle which makes a deep bright opening westward to such an extent that when off the northern side of the horn we could see Tekava far to the westward of it. The second island is followed by a third and then by an island (Tarauru-roa) nearly 2 miles long; these are separated by small gaps. Then comes a larger island (Amon) followed by three small islands separated by deep gaps.

At Vaiatekeue (not the Vaiatekeua on the chart), the reef flat becomes quite narrow; it is hardly more than 100 yards wide; the islets perhaps 50. The northern islets are small and separated by long stretches of low shingle and carry but little vegetation and very few cocoanut trees. There are but two short sand beaches all the way from the northeastern to the eastern horn of the eastern face of the encircling reef of Manga Reva. A regular dam of shingle from 10 to 14 feet high, on the top of which the usual coral reef vegetation flourishes, extends along the outer face of the reef flat, which varies from 50 to 150 yards in width, and is flanked at the base by low buttresses of modern elevated coral reef rock and of breccia in places, all more or less weather beaten and honey-combed.

The islets and their formation and their junction or division into larger or smaller islets and the gaps which separate them, the mode of formation of the buttresses, of the planed-off, hard nearly level reef flat, of the coralline mounds of the outer edge,—all these differ in no way from what has been described in other barrier reef islands and atolls of the Pacific.

The beaches of the lagoon are steep, and corals do not seem to thrive in those parts of the lagoon to which the sea does not have access or at some distance from shore. This is well shown by the vigorous growth of corals in the fringing reef to the south of Mt. Duff on the outer edges of the reef patches of Port Rikitea, and on the spits which connect Au Kena with

Manga Reva, in contrast with those along the west face of the lagoon flats to the west of the eastern barrier reef.

There is a northeast horn of the eastern barrier reef in the extension of Manga Reva Island, forming the northern culmination of the central bight of the eastern face of the barrier reef. From that point the reef flat runs westerly to form the northern horn about 3 miles north of Manga Reva Island. The position of the outer reef cannot be correct on the chart (H. O. No. 2024). On leaving Manga Reva we made three soundings close off the reef flat line of breakers—one off Tekava, at the most $\frac{1}{2}$ of a mile from the reef, in 225 fathoms. Our position, plotted by tangents to the volcanic islands or by their summits, indicated in this case, on the chart, a distance of $1\frac{1}{2}$ miles. A second sounding of 245 fathoms off the eastern horn at less than $\frac{1}{2}$ mile, indicated on chart No. 2024 a distance of 2 miles from the horn; and a sounding of 241 fathoms $\frac{1}{4}$ of a mile off the point which we had visited (Vaiatekeue) indicated a distance of $\frac{3}{4}$ of a mile on the chart.

The slope of the Gambier Archipelago to the east is steep. On coming in sight of Manga Reva we sounded in 2070 fathoms at a distance of 11 miles from Mt. Duff, that is, 6 miles from the outer edge of the reef bearing southwest; and on coming out we sounded again half-way to that point at a distance of $3\frac{1}{4}$ miles from the breakers in 1394 fathoms.

One cannot fail to be struck with the similarity of the Manga Reva Archipelago with the great atoll of Truk. If I remember rightly, Darwin also called attention to this from a study of the charts. Yet, owing to the great size of Truk, no less than 125 miles in circumference, and the great distance of the barrier reef from the encircled volcanic islands, the effect as one steams into Manga Reva is totally different from that produced by Truk. In the latter some of the islands, though large, and of the same height as those of Manga Reva, are much more scattered, and seem of comparatively small importance in the midst of the huge lagoon which surrounds them. The barrier reef islets of Truk are from 11 to 15 miles distant from the encircled volcanic islands. In Manga Reva, which is only 45 miles in circumference, after passing the small islands in the southern and open part of the lagoon when once off Maka-pu, we can fairly well take in the atoll as a whole. The western island (Tara Vai) is only 5 miles off; Manga Reva and An Kena are about 3, as are also the islets of the east face of the barrier reef; these distances, as you approach the entrance to Rikitea, are constantly growing less, so that when in the gap between Manga Reva Island and An Kena, at the foot of Mt. Duff, none of the larger islands are more than 3 miles off; and the islets of the eastern face of the barrier reef

are seen to the northeast about 4 miles off. When on the summit of the central ridge of Manga Reva one can, in a radius of a little more than 4 miles, take in the whole panorama of Manga Reva, and get an impression of the relations of its different part far better than can be conveyed by the chart, for the whole of the visible part of the archipelago is included in a line drawn east and west, south of Maka-pu; south of that line the position of the southwestern reef can be traced only by the discoloration of the waters.

Manga Reva is an intermediate stage of erosion and denudation, between a lagoon archipelago such as Truk, and a barrier reef island like Vanikoro, and other islands in the Society groups such as Bora Bora,* Huaheine, Raiatea, Eimeo, in which the surrounding platform has comparatively little width and the barrier reef is close to the principal island and often becomes part of its fringing reef. Manga Reva is open to the south and to the west, Vanikoro to the east, while the volcanic islands of Truk are completely surrounded by the outer encircling barrier reef, as are the Society Islands just mentioned, which have several wide passages into the lagoon through the wide barrier reef.

One is tempted to reconstruct the Gambier Archipelago of former times and to imagine it with a great central volcano, of which Manga Reva and Au Kena are parts of the rim which once were connected from the southeast point of Manga Reva to Au Kena, and thence along the line of the outer islets to the northeast end of the former island with a deep crater of more than 34 fathoms. On the west face it was flanked by smaller craters extending to the western islets of the barrier reef, of which the bays of Taku, Kirimiro and Rumaru, and the bays of the west side of Tara Vai are the eastern ridges. There were probably also other secondary volcanoes, of which Aka Maru and the islets of the south part of the lagoon are the remnants, the latter all being situated on the gentle slope of the southern part of the Manga Reva plateau; this may have been the southern slope of the principal volcano of the group, on the face of which have grown up the outer lines of the barrier reef and its islets.

The existence of a large central volcano would readily explain the depth of the lagoon in its different regions, as well as the great depth off the outer face of Manga Reva, depths showing slopes which are no steeper nor more striking than the height and slopes of the southern part of Manga Reva or Tara Vai, of Aka Maru, and of Maka-pu, supposing them to be extended into the sea.

*See A. Agassiz,—The Coral Reefs of the Tropical Pacific, Plates 210 and 281.

Mt. Mokoto and Mt. Duff drop precipitously for more than one-third their height and in less than a quarter of a mile fall from over 1300 feet to the level of the sea. Similar slopes are found along the volcanoes of Easter Island where there are no coral reefs. The edge of the crater of Rana Kao drops perpendicularly a height of nearly 1000 feet in less than one-eighth of a mile horizontal distance; and the eastern face of the crater of Rana Roroka rises vertically about 800 feet above the plain of Tangariki.

It is interesting to note how poor is the flora of the Manga Reva Archipelago as compared with that of the more western volcanic islands like the Marquesas and the Society Islands and some of the western elevated Paumotus. In the Gambier Archipelago the forests are reduced to a few patches extending along the small valleys of the slopes of the volcanic spurs. I am informed that even in the thirties of the last century, when the missionaries first landed at Manga Reva, the forest trees, while more numerous, yet never attained the luxuriance of growth that they attain in the Society and Marquesas Islands. At the present day, with the exception of the forest patches just mentioned and a few trees which have been introduced for cultivation, the islands of the group are in great part thickly covered with a species of cane closely resembling that of our Southern States. The fauna of Manga Reva is also extremely poor. There are no mammals, and with the exception of a "sandpiper" no indigenous birds. Sea birds are few in number, and in our trip in the Eastern Pacific we rarely had more than three or four birds accompanying us; often only one, and frequently none was visible for days. There are a few lizards on the islands, apparently of the same species as those in the Society Islands.

We left Port Rikitea for Acapulco on the 4th of February to anchor off Aka Maru; on the 5th we left our anchorage, sounded off the east face of Manga Reva, and took photographs.

On our way north from Manga Reva to Acapulco we did not begin to trawl or tow until warned by the surface nets that the surface was becoming richer in animal and vegetable life and also by the surface temperatures indicating that we had reached the southern edge of the cold western equatorial current. A little north of 10°, south latitude, we made our first haul and deep tow, and found a very rich fauna down to the 300 fathom line, recalling the pelagic fauna of the eastern lines and fully as rich. On trawling we found, as we expected, a very rich bottom fauna.

Among the animals brought up in the trawl there were some superb *Hyalonemas*, siliceous sponges, *Benthodytes* and

other deep-sea holothurians, fine specimens of *Freyella*, and some large ophiurans. This haul is interesting as showing that in the track of a great current, with abundance of food, we may find at a very considerable depth (2422 fathoms) an abundant fauna at very great distances from continental lands. We were, at this station, about 2140 miles from Acapulco, 1200 miles from Manga Reva, 1700 miles from the Galapagos, and about 900 miles from the Marquesas.

Another haul made under the equator near the northern edge of the cold current in 2320 fathoms gave us the same results. The pelagic fauna was very abundant, the surface teemed with radiolarians, diatoms, and Globigerinæ and swarmed with invertebrates. The trawl contained a superb collection of bottom species of holothurians, *Brisinga*, *Hyalonema*, *Neusina*, and on this occasion we brought up the only stalked crinoid collected during this expedition—parts of the stem of two specimens of *Rhizocrinus*, of which, unfortunately, the arms were wanting.

Our progress, which was excellent during the first days of our journey after leaving Manga Reva, has for the past six days been greatly impeded by head winds in the region where we ought to have been in the full swing of the southeasterly trades. This led us to abandon with great reluctance all idea of further work in the equatorial belt of currents; to give up our proposed visit to Clipperton, and on account of our limited coal supply, to make for Acapulco, merely sounding every morning. This was a great disappointment to me, as we had every reason to expect to be able to spend some time in the region of the equatorial current's belt and settle more conclusively than we have been able to do the question of their influence upon the richness of the fauna living in their track far from continental shores or insular areas.

The presence of diatoms in all parts of the Humboldt Current, which we crossed from south of Callao to the equator at the Galapagos and west towards Clipperton, shows how far the track of a great oceanic current can be traced, not only by its temperature but also by the pelagic life within or near it. When once in the warm westerly equatorial current the diatoms disappear and the bottom samples show only surface radiolarians and Globigerinæ.

We took a number of serial temperatures in the line Galapagos to Manga Reva, passing from the colder water of the Humboldt Current to the warmer waters south toward Manga Reva. The temperatures at 200 fathoms became nearly identical. North the great change in temperature took place between 25 and 200 fathoms, where there was a difference of 24° . South the warm water extended 100 fathoms, a great change occurring

between 100 and 200 fathoms, a drop of 16° . The serial temperatures taken at the southern and northern edges of the cold current on the line Manga Reva-Acapulco agreed well with those taken in the same current to the east.

The samples of the bottom obtained by the soundings taken by the expedition or gathered in mud-bag and in trawl indicate that an immense area of the bottom of the Eastern Pacific is covered with manganese nodules, and that they play an important part in the character of the bottom, not only in the area covered by this expedition; the area of manganese nodules probably extends to the northwest of our lines to join the stations where manganese nodules were found by the Albatross in 1899 in the Moser Basin, on the line San Francisco to Marquesas.

This area may also extend south of our lines Callao to Easter Island, and join the line west of Valparaiso where the Challenger obtained manganese nodules at many stations. I do not mean to imply that manganese nodules are present to the exclusion of radiolarians and of Globigerinæ. It is probable that the layer of nodules are partly covered by them, and by the thick, sticky, dark chocolate-colored mud which is found wherever manganese nodules occur.

During this expedition we sounded every day while at sea and developed very fairly that part of the Eastern Pacific which lies to the south and west of the line from Cape San Francisco to the Galapagos and west of a line from Galapagos to Acapulco, limiting an area occupied by the Albatross in 1891. The area developed by us is included by a line 3200 miles in length from Acapulco to Manga Reva and the area north of a line from Manga Reva to Easter Island and from Easter Island to Callao. We developed on our line Galapagos to Manga Reva the western extension of the Albatross Plateau, and found it of a depth varying from 1900 to somewhat less than 2300 fathoms in a distance of nearly 3000 miles; about half-way from the Galapagos to Manga Reva we came upon a ridge of about 200 miles in length with a depth of 1700 to 1055 fathoms, dropping rapidly to the south to over 1900 fathoms. I propose to call this elevation Garrett Ridge.

Our line from Manga Reva to Acapulco continued to show the western extension of the almost level bottom of the Eastern Pacific. In a distance of 3200 miles the depth varied only about 400 fathoms. This great area was practically a mare incognitum. Three soundings in latitude 20° south towards the Paumotu and five soundings in a northwesterly trend from Callao to Grey's Deep, are all the depths that were known previously of this great expanse of water. This existence of the great plateau dividing Barber Basin along the South American coast from Grey and Moser Basins to the west is most interest

ing. It recalls the division of Southern Atlantic into an Eastern and Western Basin by a central connecting ridge, the Challenger ridge. The Albatross Plateau joins the western extension of the Galapagos Plateau as developed by the Albatross in 1891.

The existence of a sounding of 2554 fathoms near the equator in longitude 110° west would seem to indicate a small basin included in this plateau disconnected from Grey's Deep and Moser Basin by its extension to the west. How far west towards these basins that extension reaches, no soundings indicate as yet. It is interesting to note that along the Mexican coast there are a number of deep basins lying disconnected close to the shore just as there are a number of disconnected deeps close along the South American coast extending from off Callao to off Caldera, Chili, opposite high volcanoes or elevated chains of mountains. These basins and a great part of the steep Mexican continental shelf are deeper than the Albatross Plateau to the south, and form a deep channel, separating in places the Plateau from the steep continental slope. The steepness of the continental shelf is well seen, especially off Acapulco and Manzanilla. One of the small basins along the Mexican coast with 2661 fathoms lies off Sebastian Viscaino Bay; another with more than 2900 fathoms is to the west of Manzanilla Bay; a third to the southeast of Acapulco has about the same depth, and a fourth with 2500 fathoms is off San Jose, Guatemala. Our last soundings off Acapulco about 29 miles south of the lighthouse, in 2494 fathoms, showed the western extension of one of these deep holes to the east of Acapulco. These basins off the west coast, close to the shore at the foot of a steep continental slope, are in great contrast to the wide continental shelves which characterize the east coast of Central America and the east coast of the United States.

The collections made during the present expedition will give ample material for extensive monographs on the holothurians, the siliceous sponges, the cephalopods, the jelly-fishes, the pelagic crustaceans, worms and fishes of the Eastern Pacific, as well as on the bottom deposits and on the radiolarians and dinoflagellates, diatoms, and other protozoans collected by the tow nets. Small collections of plants were made at Easter Island and Manga Reva which may throw some light on the origin and distribution of the flora of the Eastern Pacific.

ART. XL.—*Note on the Names Amphion, Harpina, and Platymetopus*; by PERCY E. RAYMOND.

AFTER my recent paper on the Chazy Trilobites (Annals Carnegie Museum, vol. iii, No. 2) was in type, Dr. W. J. Holland called my attention to the fact that the name *Amphion* was in general use for a common genus of moths. A little investigation showed that not only *Amphion*, but *Harpina* and *Platymetopus*, two other generic names used in the paper cited, were likewise preoccupied.

The first use of *Amphion* as a generic name was by Hübner, who, in 1816, applied it to one of the Lepidoptera.* Pander proposed the same term for a trilobite, in 1830,† and designated *Amphion frontiloba* = *Asaphus Fischeri* Eichwald as the type. Since *Amphion* is thus preoccupied, it becomes necessary to find some other name to apply to this trilobite. Angelin, in 1854,‡ used *Pliomera* as a new generic designation for trilobites of the type of *Asaphus Fischeri* Eichwald, evidently intending to restrict the genus to its original meaning. This name *Pliomera* should now be adopted to replace the preoccupied name *Amphion* Pander.

The Chazy species *Amphion canadensis* differs in several particulars from the European form *Pliomera Fischeri*. In the American species the median furrow of the glabella is very faint and frequently absent; the second pair of furrows are much further apart, thus producing one large frontal lobe instead of two small ones as in the Russian species; the facial sutures reach the lateral margin in front of the genal angles; the frontal border is not denticulate, and the two species do not have the same number of thoracic segments.

The absence of the median glabellar furrow and of the denticulate margin seem to be of considerable taxonomic importance, as this furrow cannot be regarded as due to the mechanical effect produced by the enrollment of the animal in pressing the spinose tail against the glabella. This is proved by the fact that no pygidial spine is situated opposite the median furrow, but that the two median spines of the pygidium are placed so that one comes on either side of the frontal furrow. Again, the second pair of glabellar furrows are longer than this median furrow, and the third set is still longer, as would be the case if all were glabellar furrows. Finally, in *Amphion canadensis* there is a smooth border around the front, and the median indentation is almost obsolete, while the pygidium

* Verzeichniss bekannter Schmetterlinge.

† Beiträge zur Geognosie des russischen Reiches, p. 139.

‡ Palæontologica Scandinavica, p. 30.

is exactly similar to that in the European species. If this median indentation does represent the first pair of glabellar furrows, and *Amphion canadensis* has lost it and the denticulate glabellar margin as well, then *Pliomera Fischeri* denotes an earlier stage in the development, and it will probably be best to separate the American forms under the name *Pliomerops*, with *Amphion canadensis* as the type. *Amphion convexus* Billings and *Amphion Westoni* Billings appear to belong to this subgenus. In regard to *Amphion Barrandei* Billings states that a small median pit is present in exfoliated specimens,* indicating the presence of this median furrow in a rudimentary but deep-seated condition.

The generic term *Harpina* was first used by Burmeister, in 1844, for a species of Coleoptera,† while Böck used it for a crustacean, in 1870.‡ Novák proposed the name a third time, in 1884, for a subgenus of *Harpes*,§ using it to designate the Lower Silurian forms of the genus. The hypostoma differs in the Upper and Lower Silurian species, and it was on this difference that the two genera were separated. The hypostomas of the Chazy forms are not known, but it is probable that they will be found to agree with those of the species from the Ordovician investigated by Novák. In any event, it is necessary to supply a new name in place of the preoccupied *Harpina*, and *Eoharpes* is herewith suggested.

Platymetopus was first used by Dejean, in 1829, for a species of Coleoptera,|| and by Angelin, in 1854, for a subgenus of *Lichas*.¶ In 1902, Reed** saw that the name was preoccupied and suggested *Paralichas* to take its place. Unfortunately this name had been applied by White, in 1859, also for a species of Coleoptera,†† hence it will be necessary to give a new name for species of Division 3 of Schmidt, of which *Lichas lævis* Eichwald is the type.‡‡ For this purpose, *Amphilichas* is proposed, and should be applied to the Chazy species now known as *Platymetopus minganensis*.

Paleontological Laboratory, Yale University Museum, March 23, 1905.

*Paleozoic Fossils Canada, pp. 288, 321, 322.

†Handbuch der Entomologie.

‡Overs. Dan. Selsk.

§Studien an Hypostomen der böhm. Trilobiten, No. 2, p. 4.

||Species général. des Coléoptères. vol. v, p. 815.

¶Palæontologica Scandinavica, p. 68.

**Quart. Jour. Geol. Soc. London, vol. lviii, pp. 62, 89.

††Ann. Mag. Nat. Hist., ser. 4, vol. iii, p. 284.

‡‡Rev. der Ostbalt. Silur. Tril. Mém. Acad. Imp. St. Petersbourg, ser. 7. vol. xxxiii, No. 1, p. 49.

ART. XLI.—*The Bragdon Formation* ;* by J. S. DILLER.

Introduction.—The Bragdon formation of Shasta and Trinity counties, California, was named by Mr. O. H. Hershey† and regarded by him as Jurassic. The first fossils found‡ by my party tended to confirm his view, but later§ upon structural grounds it was referred provisionally to the lower part of the Carboniferous. This called forth an article|| from Mr. Hershey maintaining at length his original views. Last summer other fossils were discovered in the Bragdon confirming its reference to the Carboniferous, and this article is intended to present the evidence.

Lithological character.—The Bragdon formation was designated by Mr. Hershey¶ to include an extensive series of thin-bedded shales, sandstones and conglomerates lying some miles north and northwest of Redding in Shasta and Trinity counties, California. The dark, often black, shales in strata ranging from a foot to sixty feet in thickness alternate with thin beds of sandstone and conglomerate. The sandstones are usually normal although sometimes dark, hard, and flinty, like quartzite and occasionally tuffaceous, but as Hershey says, and I fully agree, “the conglomerates are the most characteristic portion of the series.”**

They are generally composed in large part of black and gray pebbles of quartz with others of sandstone, shale and limestone. Generally they contain no igneous material, but in some places it becomes abundant. By weathering, the limestone pebbles disappear leaving holes upon the surface, thus giving to the conglomerate a peculiar porous aspect. The beds of conglomerate are usually less than ten feet in thickness, but sometimes attain a maximum of nearly fifty feet. Quartz and chert pebbles prevail in the smaller and finer beds and sometimes also in the larger beds where the pebbles are not over half an inch in diameter. As the beds become coarser pebbles of sandstone become most abundant, while those of limestone also generally increase in number and size.

The Bragdon conglomerate is most abundant along the Sacramento River. Much of it is fine but some of it is coarse, with one exception much coarser than that found elsewhere. It is best exposed three-fourths of a mile above Elnore and also

* Published by permission of the Director of the U. S. Geological Survey

† Am. Geol., vol. xxiv, p. 89, and vol. xxvii, p. 236.

‡ U. S. Geol. Survey, Bull. 196, p. 65.

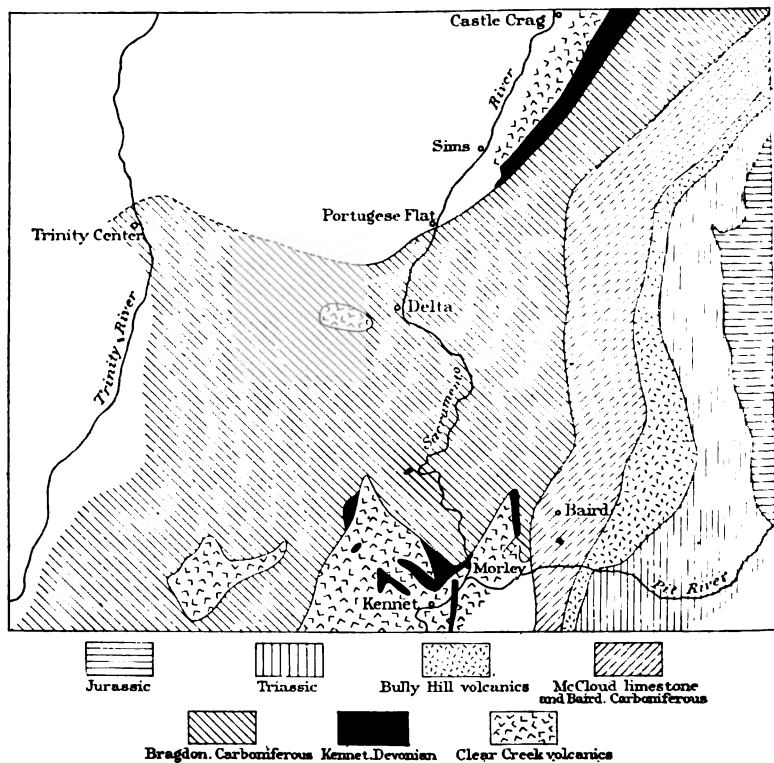
§ This Journal, vol. xv, p. 351.

|| Am. Geol., vol. xxxiii, pp. 248 and 347.

¶ Am. Geol., xxvii, p. 236.

** Am. Geol., vol. xxxiii, p. 252.

half a mile above the mouth of Middle Salt Creek; in both cases upon the left bank of the river, and sandstone cobbles predominate. They are thoroughly waterworn, round and smooth, attaining at the first locality a maximum diameter of two feet although they are generally not over six inches. Limestone cobbles are less abundant, somewhat smaller and



often fossiliferous, while pebbles and coarse sand chiefly of vein quartz and chert form the matrix between the larger fragments as well as the beds of finer conglomerate. Away from the river, coarse conglomerate is rare. It was noted on the divide, about one and one-fourth miles southwest of High Mountain, called also Nawtawakit Mountain, close to the eastern edge of the Bragdon, where the pebbles of gray sandstone weathering red are sometimes six inches in diameter and very hard.

Distribution.—The principal area of the Bragdon, and the one to which, excepting the western border, I have given special attention, is what Mr. Hershey calls the "eastern or

type area.”* As shown upon the accompanying map, it is roughly pear-shaped, constricted in the small part with the longer axis running nearly northeast and southwest. The bigger end lies near Trinity River from Lewiston to Trinity Center, while the smaller end is trenched by the Sacramento from Portuguese Flat to Morley, and the long broad stem runs northeast from North Salt Creek to the McCloud, a total length of fifty miles and maximum breadth of about twelve miles. The borders are locally irregular and there are a few small outlying masses of Bragdon, but in general this area is remarkable for its continuity from the Trinity River to the McCloud without interruption excepting a small area of Devonian on Little Sugar Loaf Creek and small areas of volcanics on Clear Creek and Dog Creek, as well as several long narrow masses, not shown on the map, east of the Sacramento River. The smaller end of the Bragdon area, including the stem lying east of the Sacramento, is bordered on the one hand by the Carboniferous sediments and on the other by those of Devonian age; but west of the Sacramento, excepting a small bit on Backbone Creek, the type area of the Bragdon is everywhere bounded by igneous rocks, some volcanic, others plutonic. It is evident, I think, that the region of greatest promise in studying the taxonomy of the Bragdon is east of the Sacramento, where it comes in contact both above and below with sediments whose horizon is well established by an abundance of fossils. West of the Sacramento we are adrift among a plexus of igneous rocks whose exact age in most cases is not easily determined.

Stratigraphy.—The Bragdon, composed as it is of thin beds, lacks a definite rigid horizon to resist folding. It is easily crumpled, giving a great variety of dips and strikes. In the part of the area east of the Sacramento the dips are sometimes vertical, but for the most part not over sixty degrees, often under thirty and generally to the eastward, and agree fully with the general position of the Jurassic, Triassic and definitely known Carboniferous (McCloud and Baird), all of which lie to the eastward and increase in age westward, suggesting that the Bragdon is the oldest and lies beneath the Baird. This view is strengthened by an examination of the eastern limit of the Bragdon where it adjoins the Baird. The limit may be traced for more than twenty-five miles parallel with the Baird and McCloud limestone, within a mile or two west of the latter, and is marked by the disappearance of the characteristic Bragdon conglomerate. It must not be supposed that the same bed of conglomerate can be traced continuously along the eastern edge of the Bragdon for twenty-five miles. The conglomerate is in thin lenticular beds with traceable continuity of

* *Am. Geol.*, vol. xxxiii, p. 251.

only a few miles, but farther along in the same horizon the conglomerate comes in again. This top horizon of the Bragdon will be noted at only two points. On Hirz Creek road the top conglomerate is fine, but west of it a few hundred feet is another that is coarse with fossiliferous Devonian pebbles. The strata are all nearly vertical and for the most part well exposed eastward to the shales full of Baird fossils. On the divide about a mile and a half southwest of High Mountain the characteristic conglomerates are well developed. Most of them are fine, but one is coarse, with many pebbles of sandstone and some of fossiliferous Devonian limestone. These lenses of Bragdon conglomerate are immediately and conformably overlain by sandstone containing Baird fossils. An observer cannot carefully study the contact of the Baird and Bragdon from one end to the other without being convinced on structural grounds alone that the Bragdon and Baird are conformable and that the former is the older.

As to the lower limit of the Bragdon, the matter is more complex owing to the fact that the basement on which it rests is variable, sometimes sedimentary rocks of Devonian age, but more frequently volcanics. The best exposure of the Bragdon resting on the Devonian is along Backbone Creek, three and one-half miles north of Kennet, where over 800 feet of Devonian shales and limestone* are overlain unconformably by a thirty-foot bed of Bragdon conglomerate containing fossiliferous Devonian fragments. To the east and west of this locality the Bragdon beds overlap the Devonian to the volcanics, but in both directions there soon appear other patches of Devonian lying between the Bragdon and the volcanics. Nearby, on Little Sugar Loaf Creek, a small area of fossiliferous Devonian is completely surrounded by Bragdon. Along this portion of the Bragdon border the small areas of Devonian are remnants left by pre-Bragdon erosion of a once continuous sheet of Devonian and thus exposing the volcanic rocks which lie beneath and were erupted before the Devonian sediments were deposited. To the northward, in the vicinity of Hazel Creek, the Devonian shales and limestone areas are more continuous and may be traced for over ten miles along the western border of the Bragdon. Although the contact is not well exposed, the fact that the basal conglomerates of the Bragdon are at least generally, if not everywhere, composed wholly of debris from the Devonian sedimentary rocks, clearly indicates an unconformity by erosion between them.

It is in this portion of the pear-shaped Bragdon area that its taxonomy is most evident and may be conveniently studied along the trails from the McCloud to Castle Crag and Sims on

* This Journal, vol. xv, p. 347.

the Sacramento. The essential part of the McCloud-Sims section is given below, beginning with the newer beds on the east. The thickness given is only a rough estimate, making allowances for repetition by many small folds and faults.

Carboniferous, limestone, (McCloud)	2000
“ reddish shales and sandstones with much volcanic material (Baird)	1000
“ shales, sandstones and tuffs with siliceous conglomerates (of Devonian pebbles) increasing in number and size from the top towards the bottom (Bragdon)	2900
(Unconformity)	
Devonian, dark shale	100
“ limestone	150
“ black slaty shales (scarcely any chert)	400
? volcanic series	

Relation of the Bragdon to Volcanic Rocks.—The Redding quadrangle contains an extensive series of highly fossiliferous sediments from the Devonian to the Tertiary inclusive, and affords one of the most complete records of the volcanic phenomena of that interval to be found in the state of California. This is not the place to enter into details concerning this record, and yet it is necessary to consider it very briefly in a general way to elucidate the relations of the Bragdon. Devonian sediments show the existence of andesitic and rhyolitic lavas of earlier date, and during the Bragdon and especially the earlier portion of the Baird there was considerable volcanic activity which continued for a long time and culminated about the close of the Paleozoic. A great sheet of lava and tuffs was formed at that time which appears between the Carboniferous and Triassic sediments. Volcanic eruptions continued at intervals throughout the Triassic and Jurassic but during the Cretaceous there was a long interval of quiescence, followed by the great eruptions of the Tertiary. It is not to be supposed that volcanic products were in all cases spread equally over the whole Klamath Mountain area for each volcanic horizon. The eruptions were local, yielding large masses at different places at different times, and to establish the horizon of each it is generally necessary to determine their relation to fossiliferous sediments.

Older than the Miocene, one of the largest among half a dozen horizons of volcanic products in the Redding quadrangle is that on the border of the Paleozoic and Mesozoic. The andesitic and rhyolitic lavas and tuffs of that horizon form a prominent ridge to which Bully Hill belongs, and the whole mass may be conveniently referred to as the “Bully Hill volcanics.” Con-

cerning the age and structural relations of the Bully Hill volcanics, all observers practically agree in placing them about the close of the Paleozoic and the beginning of the Mesozoic, but as to the age of the large area of volcanics southwest of Bully Hill, along the Sacramento—the rocks which Mr. Hershey has called his Clear Creek volcanic series, I have but recently come to a definite conclusion. The generally complete absence of volcanic material in the typical Bragdon conglomerates, and also the fact that much of the igneous material which appears in the areas of "Clear Creek volcanics" cuts the Bragdon, for a long time counterbalanced in my mind the contention of Hershey that the Bragdon is younger than the "Clear Creek volcanic series" and rests directly upon it. But the discovery of andesitic and rhyolitic material like that of the Clear Creek series in certain Bragdon conglomerates well characterized by fossiliferous pebbles of Devonian limestone, leaves no doubt that in the main the "Clear Creek volcanics" near the Sacramento are, as Hershey maintains, older than the Bragdon.

On Backbone Creek, several miles above Kennet among the stratified rocks which appears to belong to the Devonian, there are definite beds of volcanic debris which indicate that andesites and rhyolites, like those of the "Clear Creek volcanics," were exposed to furnish Devonian sediments. The relation of the Devonian limestone and shales in the Kennet region to the "Clear Creek volcanics" confirms the same view. The Devonian sediments appear in patches completely surrounded by the "Clear Creek volcanics," at first suggesting that the Devonian sediments are broken up and enclosed by the volcanics. On closer examination, however, the isolated patches of Devonian are clearly seen to be, for the most part, remnants of a once continuous but deformed sheet of Devonian that covered the "Clear Creek volcanics" of that region, and was cut up by pre-Bragdon erosion into separate patches exposing larger areas of the underlying volcanics. A few miles northwest of Kennet the Devonian patches lie on ridges completely separated by the narrow canyon of Little Backbone Creek, but on Backbone Creek erosion has not yet quite completed the separation of the Devonian masses upon its sides.

The "Clear Creek volcanics" of the Kennet area which are beneath the Devonian, Mr. Hershey regards as on top of the Devonian. If his view were correct, they should lie between the Bragdon and the Devonian, which is certainly not true in the Kennet region where all three are well exposed, and in every Devonian outcrop touched by both Bragdon and "volcanics" the former is on top and the latter beneath. This relation is clearly exposed at two points on Backbone Creek, also on Little Sugar Loaf Creek, at the head of Bailey Creek,

four miles west of Baird and near the mouth of Hazel Creek. It is evident, therefore, that the "Clear Creek volcanics" of Hershey in the Kennet region, being earlier than the middle Devonian, are not equivalent to the Bully Hill volcanics of late Carboniferous and early Triassic age. The fossiliferous tuffs and shales which are interstratified with the lavas of "Bully Hill volcanics," showing them to be of submarine eruption, are entirely lacking in the "Clear Creek volcanic series."

The general statements made in this paper apply only to the type areas of the Bragdon and of the "Clear Creek volcanics" east of Trinity Mountain, where it is believed their normal relations to Carboniferous and Devonian are better exposed than anywhere else in the Klamath Mountains.

Age of the Bragdon.—The Bragdon formation is regarded by Hershey as Jurassic about the horizon of the Mariposa, and he has set forth his evidence in detail.* It is in part lithological but largely structural, in which much stress is laid on the relative position of his "Clear Creek volcanics" regarded as of early Triassic age, but which, as I have already shown, are in part, at least, earlier than the middle Devonian.

Upon a geological map of portions of the copper belt of Shasta County, Anderson† represents the same rocks as Triassic, but the circumstances of publication did not permit him to present the evidence.

A study of the areal distribution of the Bragdon and its stratigraphic relation to the Carboniferous and the Devonian led me several years‡ ago to refer it provisionally to the lower part of the Carboniferous. Further field study has confirmed me in that opinion as already set forth. Fossils recently discovered support the same conclusions and will now be considered.

Mr. James Storrs, who has collected most of the fossils for my party of the Geological Survey in the Redding Quadrangle, early discovered that some of the limestone fragments of the Bragdon conglomerate are fossiliferous. Fossils have been collected at various times during four years from the conglomerate pebbles at twenty-one localities, chiefly along the Sacramento and to the eastward close up to the outcrop of the Baird formation, but also to the westward as far as Trinity Mountain and on the northwest to within a few miles of Trinity Center. These fossils were referred at first to Mr. Schuchert and later to Dr. Girty, and all of them as far as determinable, with one possible exception found on Bailey Creek to be mentioned later, were

* Am. Geologist, vol. xxxiii, pp. 248-256 and 347-360.

† State Mining Bureau, Bull. 23, 1902, on Copper Resources of California.

‡ This Journal, vol. xv, p. 852.

reported as Devonian like those already known in the region. The Devonian fossils in the pebbles simply show that the conglomerate is later than the Devonian.

Careful search was made in the paste of the conglomerate as well as in the associated sandstones and shales for fossils of the Bragdon epoch. Fossils were found in eleven localities, enumerated below, at six of which the fossils are in shales and sandstones, associated with the characteristic Bragdon conglomerate, while at the other five the fossils occur in the paste of the conglomerate, but not in the pebbles.

One of the most important occurrences is upon the divide southwest of High Mountain, where the sandstones conformably interbedded with characteristic Bragdon conglomerate contain shells which Dr. Girty reports as "Paleozoic, and without much doubt early Carboniferous, related to the Baird." The fossils, among which is a large "Spirifer of the Striatus type," occur in several beds. The exposures are good and leave no doubt that the fossils are of the Bragdon horizon.

Perhaps the most important locality is beside the railroad, one and one-half miles northeast of La Moine, where fossils were found in the sandstone adjoining the Bragdon conglomerate. From this locality Dr. Girty reports *Schizodus* sp., *Loxonema* sp., *Pleurotomaria*? sp. and *Straparollus* aff. *S. luteus*. There is no room for doubt that these fossils belong to the Bragdon and are not derived from an older formation, and Dr. Girty remarks that if this be admitted "no other conclusion is possible than that the Bragdon is a Paleozoic formation. Indeed it is fairly safe to say that the horizon is not later than Baird, for the local faunas have many points of resemblance with that of the Baird, and none at all with those of the overlying Carboniferous formations."

From the shales about two and one-half miles southwest of the mouth of Hirz Creek, and also from shales in an isolated patch of the Bragdon about one and one-fourth miles a little east of south from Bayha, Cephalopods were collected. From the first locality Dr. Girty reports *Glyphioceras*, and from both a form "of what seems to be a *Nautiloid* to which Mr. Stanton recalls nothing similar in the Mesozoic and which is not out of place in the Carboniferous." Dr. Girty states further that "The little *Goniatite* shows only the course of the suture lines, external characters being concealed. The sutures remind me much of those of the *sphaericus* group of *Goniatites* (*Glyphioceras*), and if this is truly the relation of the specimen the age would probably be late Lower Carboniferous. Prof. J. P. Smith, who examined the specimen, on the other hand, thinks that it might represent an immature stage of an *Ammonite*. It seems to me, however, that an

Ammonitic stage sufficiently immature to show sutures of the simplicity of the present example would be of a size much smaller than it possesses. In my opinion, therefore, the specimen is a *Glyphioceras*, but the possibility should not be lost sight of that it may be a young stage of a more complicated and later developed type."

We now come to the fossils found in the paste of the Bragdon conglomerate. Dr. Girty identifies *Lithostrotion sublaeve*, a Baird species, from one and one-half miles east of Portugee Flat, and also on O'Brien Creek, one-fourth mile below the stage road. No other fossils were found at either place.

On Hazel Creek, six miles east of Sims, there is a conglomerate composed largely of volcanic material with but little chert and therefore not typical Bragdon. It includes what look like fragments of rotten calcareous sandstone which readily disintegrate, leaving very distinct and complete impressions of delicate parts of corals against the paste in such a way as to indicate, as pointed out by Dr. Girty, that the fossils are in place and not derived. Dr. Girty recognizes from this locality *Zaphrentis* sp. and *Loxonema* sp., and the last, if not both, appears to belong to the Baird.

The only case in which there is reasonable doubt concerning the relations of the fossils has already been referred to. It is on Bailey Creek, where a Bragdon conglomerate contains *Zaphrentis* and *Loxonema*? in moderately soft sandstone having the form of a small pebble, while there is a suggestion in the arrangement of the fossils that, as on Hazel Creek, they are contemporaneous, yet the evidence is not clear. If it is a pebble, two explanations may be offered. There is the possibility and perhaps probability on the one hand that the forms mentioned may have begun in the Devonian, and from thence have been derived, or, on the other hand, that they may not be the identical forms of the Baird.

In estimating the weight of the evidence afforded by this one doubtful pebble containing more or less questionable forms, it is necessary to remember that the fossils in the sandstones and shales, as well as the matrix of the Bragdon conglomerate, point definitely to the conclusion that the Bragdon formation is Paleozoic and is fully in harmony with the stratigraphic evidence which places the Bragdon at the base of the Carboniferous section conformable beneath the Baird.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Preparation and Properties of Tantalum.* — Metallic tantalum has been prepared by Berzelius, Rose, and more recently by Moissan, but always in an impure condition, either as a black powder, or, in Moissan's case, as a very hard, brittle substance containing carbon. WERNER VON BOLTON has recently succeeded in obtaining tantalum in a practically pure condition, and finds that it possesses some very remarkable properties which promise to make the metal one of great practical importance. Von Bolton has improved the processes of Berzelius and Rose (where a double fluoride is reduced with an alkali metal) and he has purified the product further by fusing it in a vacuum by means of the electric arc. He has also applied an interesting electrolytic process, consisting in passing an electric current through slender rods of the lower oxide in a bulb similar to that of the incandescent lamp, meanwhile pumping away the oxygen formed by the electrolysis as fast as it was formed. Pure tantalum when fused forms a brilliant regulus having a platinum-gray color, which can be hammered and drawn out into the finest wire. The specific heat is .0365, and the atomic heat, 6.64, corresponds to Dulong and Petit's law. The specific gravity of the cast metal is 16.64. Its melting point was found to be 2250 to 2300°, and is far above that of platinum. It remains brilliant upon exposure to air, and oxidizes slowly when heated in air or oxygen. The metal shows an extraordinary combination of the properties of malleability, ductility, tenacity and hardness. For instance, when a red hot piece of tantalum is put under the steam-hammer, a plate of the metal is readily formed, which, when repeatedly heated and hammered, attains a hardness equal to the diamond. An attempt to bore such a plate one millimeter thick with a diamond drill with 5000 revolutions per minute had to be abandoned after three days and nights of continuous work, as a depression of only one-quarter millimeter was made thereby, and the diamond drill was much injured; still the plate could be made thinner by rolling, without losing its hardness. Many applications are predicted for this most wonderful metal, one of which is the use of the wire for the incandescent lamp, in which it gives more than double the efficiency of the carbon thread.—*Zeitschr. für Electrochem.*, xi, 46.

H. L. W.

2. *Gravimetric Determination of Nitric Acid.* — M. BUSCH has synthesized a base, diphenyl-endanilo-dihydro-triazol, named "Nitron" for the sake of brevity and for commercial purposes, which forms a very insoluble, stable nitrate, and, therefore, furnishes a means for the direct gravimetric determination of nitric acid, as well as for its qualitative detection. The reagent is manufactured on a commercial scale by Merck, and is employed

in the form of a ten per cent solution in five per cent acetic acid. For qualitative tests five or six drops of the reagent are added to 5 or 6^{ccm} of the liquid to be tested, after the latter has been acidified with a drop of dilute sulphuric acid. A white, voluminous precipitate appears immediately when considerable quantities of nitric acid are present, while with minute quantities of the acid small, brilliant, needle-like crystals are slowly formed. At ordinary temperature the reaction will detect one part of nitric acid in 80,000 of water, and it is still more delicate at 0°. Unfortunately, there are other acids which also give precipitates with the reagent, and thus chlorates, perchlorates, bromides, iodides, nitrites, chromates, sulphocyanides, ferro- and ferricyanides, picric acid, and oxalates interfere with the test.

To make the quantitative determination, the substance (containing about 0.1 g. of nitric acid) is dissolved in 80–100^{ccm} of water, ten drops of dilute sulphuric acid are added, the liquid is warmed nearly to boiling and 10–12^{ccm} of the previously mentioned solution of the reagent are added. The vessel is then allowed to stand 1½–2 hours in ice-water, the precipitate is filtered on a Gooch crucible and washed with a minimum quantity of ice-cold water. The precipitate is dried at 110° for three-quarters of an hour, and the calculation is made from the formula $C_2H_3N \cdot HNO_3$, which contains only about one-sixth of its weight of HNO_3 . Numerous test analyses, some of them made in the presence of $NaCl$, $CuSO_4$, and $AgNO_3$, show excellent results.

It appears probable that this method will find considerable practical application, for heretofore there has been no method for precipitating and weighing nitric acid.—*Berichte*, xxxviii, 861.

H. I. W.

3. *The Unity of Thorium*.—Several years ago Baskerville announced that he had obtained fractions of thorium oxide showing varying specific gravities, which led him to believe that thorium was not a simple element; and in 1904 he advanced the view, based chiefly upon atomic weight determinations with different fractions obtained by volatilizing thorium chloride, that thorium contained three elements, berzelium, thorium (new), and carolinium, with atomic weights 212, 220, and 255, respectively.

R. J. MEYER and A. GUMPERZ have made a critical study of the volatilization of thorium chloride and of the atomic weight determination in such fractions, but they have been unable to find any evidence of the splitting up of our previously accepted thorium. They show that the method of determining the equivalent weight of thorium used by Baskerville was probably entirely unreliable (and was one which Krüss and Nilson, who have done the best work on this atomic weight, were also unable to use). They produced fractions of thorium chloride which should have corresponded to the so-called berzelium, etc., and obtained, by an accurate method of equivalent weight determination, perfectly constant results.

As further evidence of the unity of thorium, G. EBERHARD has made a careful study of the arc spectrum of many samples of thorium material, including fractions made by a process of crystallization by the late Dr. Drossbach, fractions of the chloride by R. J. Meyer, and other preparations from thorite, fergusonite, yttrialite, and uraninite, and he has found no evidence that any separation of thorium into several components has taken place, or has even been begun. He concludes that the results of his observations show that any element different from the old thorium could be present in these samples only in very insignificant quantity.—*Berichte*, xxxviii, 817, 826. H. L. W.

4. *Nitroxy! Chloride*.—According to the results of several investigators, the acid chloride NO_2Cl has been supposed to have been prepared, by the action of chlorine upon NO_2 , by the action of chlorine upon silver nitrate, and the reaction of NO_2 with PCl_5 . Other investigators have been unable to confirm the existence of this compound, and now GUTBIER and LOHMANN have made an elaborate series of experiments using all the suggested methods of preparation, and they have arrived at the conclusion that this "chloride of nitric acid" has not yet been produced.—*Jour. prakt. Chem.*, lxxi, 182. H. L. W.

5. *The Heusler Magnetic Alloys*.—These alloys consist of manganese, aluminium and copper; which under suitable proportions and conditions of temperature shows a magnetic state comparable with that of cast iron. E. GUMLICH has made a careful study of two specimens of the following constitution:

1. Cu 61.5 per cent, Mn 23.5 per ct, Al 15 per ct, Pb 0.1 per ct.
2. Cu 67.7 " Mn 20.5 " Al 10.7 " Pb 1.2 "

The magnetic measurements were made with cylindrical rods 18^{cm} long and 0.6^{cm} diameter. Since the molecular conditions under changes of temperature promised to throw the most light upon this remarkable manifestation of magnetism in an aggregation of non-magnetizable metals, Gumlich submitted the alloys to a considerable range of temperature during the magnetic measurements. At the temperature of liquid air no marked change was observed. Considerable changes, however, ensued on raising the temperature of the alloys. With a field strength of $H = 150$ the flux of induction was noticeably greater in alloy 1, which contained the larger proportion of manganese and the smaller proportion of lead. The rods were submitted first to a temperature of 79° in alcohol steam for nine hours, and afterwards to 110° (melting point of toluol) for 27 hours. Rod 1 showed no marked change; but in the case of rod 2 there was a marked change of flux of induction, coercitive force, residual magnetism, and maximum permeability. L. Austin finds that the alloy resembles the magnetic metals in its volume-changes in a strong magnetic field.—*Ann. der Phys.*, No. 3, 1905, pp. 535–550. J. T.

6. *A High Frequency Alternator*.—W. DUDELL describes an alternator which was primarily used in experiments on the resistance of an electric arc in which the interesting result was

obtained that this resistance with each increase of frequency behaved more like a solid resistance. The alternator was altered until the very high frequency of 120,000 cycles per second was obtained. The alternator was first driven by a figure of eight drive consisting of two bicycle wheels, one fixed direct to the motor shaft as the driving wheel, the other acting as a tension pulley to balance the pull on the alternator spindle. A surprising amount of power was required to drive the bicycle wheel at high speeds even without the inductor, and the author computes that the air friction on a single bicycle wheel running at 1200 revolutions per minute, or at a rim velocity of about $85\frac{1}{2}$ miles per hour, required an expenditure of energy at the rate of about 200 watts; so that a cyclist to attain this speed would have to develop over one-half horse power to overcome the air friction on his wheels alone. The bicycle wheels were replaced by two phosphor-bronze discs, both being made drivers. The author describes his difficulties with belts. A cotton cord three-sixteenths of an inch in diameter gave the best results. In spite of every care all attempts to run the inductor at 1000 revolutions per second failed from the axis of inertia of the inductor not coinciding with its mechanical axis. If these axes were parallel and 1^{mm} apart, the pressure at 1000 revolutions per second on the two bearings would amount to 0.8 metric ton, which would be prohibitive on such small bearings. The inductor consisted of laminated toothed discs of iron which revolved between two pole tips provided with coils. A current of 0.1 ampere was obtained at a frequency of 120,000 per second. As an illustration of this high frequency the author remarks that in plotting curves for ordinary frequencies of 50 to 100 cycles per second the scale often adopted is 10 inches for 100 cycles. If it were attempted to plot a curve up to 120,000 cycles per second the paper would require to be nearly one-fifth of a mile long.—*Phil. Mag.*, March, 1905, pp. 299, 309.

J. T.

7. *Deviation during Free Fall.*—It is still a question whether a southerly deviation of a freely falling body has ever been detected. DE SPARRE asserts that the formulæ usually given for easterly and southerly deviation during free fall are erroneous; for the variation in centrifugal force and the magnitude and direction of the weight are generally neglected. He gives mathematical expressions for the southerly deviation, according as the fall takes place in a well or from a tower. In any case the southerly deviation is too small for measurement, being less than 0.1^{mm} for a fall of 1^{km} .—*Comptes Rendus*, cxl, Jan., 1905, pp. 33-35.

J. T.

8. *Polarized Röntgen Radiation*; by CHARLES G. BARKLA. (Abstract of a paper read before the Royal Society of London, Feb. 16, 1905.)—Experiments on secondary radiation from gases and light solids subject to X-rays showed that the character of this radiation differs only very slightly from that of the radiation producing it, and that the energy of this radiation is proportional

merely to the quantity of matter through which a beam of Röntgen radiation of definite intensity passes, being independent of the kind of matter.

These results, and the agreement between the energy experimentally determined and that calculated, led to the conclusion that this radiation is due to what may be called a scattering of primary X-rays by the corpuscles or electrons constituting the molecules of the substance.

On the hypothesis that Röntgen rays consist of a succession of electro-magnetic pulses in the ether, each electron in the medium through which these pulses pass has its motion accelerated by the intense electric fields in these pulses, and consequently is the origin of a secondary radiation, which is most intense in the direction perpendicular to that of acceleration of the electron, and vanishes in the direction of that acceleration. The direction of electric intensity at a point in a secondary pulse is perpendicular to the line joining this point and the origin of the pulse, and is in the plane passing through the direction of acceleration of the electron.

On this theory, a secondary beam whose direction of propagation is perpendicular to that of the primary, will be plane polarized, the direction of electric intensity being parallel to the pulse-front in the primary beam. If the primary beam be plane polarized, the secondary radiation from the charged corpuscles or electrons has a maximum intensity in a direction perpendicular to that of electric displacement in the primary beam, and zero intensity in the direction of electric displacement.

The secondary radiation from light substances was too feeble to allow accurate measurement of the intensity of the tertiary radiation.

A consideration of the method of production of primary Röntgen rays in an X-ray tube, however, leads one to expect partial polarization of the primary beam proceeding from the anti-cathode in a direction perpendicular to that of propagation of the impinging cathode rays, for there is probably at the anti-cathode a greater acceleration along the line of propagation of the cathode rays than in a direction at right angles; consequently in a beam of X-rays proceeding in a direction perpendicular to that of the cathode stream there should be greater electric intensity parallel to the stream than in a direction at right angles.

Such a beam was therefore used as the primary radiation, and the intensity of secondary radiation proceeding in a direction perpendicular to that of propagation of the primary beam from a radiator placed in that beam, was studied by means of electroscopes.

In the final form of apparatus the intensity of secondary radiation was measured in two directions perpendicular to that of propagation of the primary radiation and to each other, while the intensity of the primary beam was measured by a third electroscope.

Using paper, aluminium, or air as the radiator, as the bulb was turned round the axis of the primary beam studied, the intensity of a secondary beam was found to reach a maximum when the direction of the cathode stream was perpendicular to that of propagation of the secondary beam, and a minimum when these two were parallel, one electroscope recording a maximum rate of deflection when the other recorded a minimum. Many experiments were made which proved the evidence of partial polarization conclusive.

When heavier metals, such as copper, tin, and lead, which emit a secondary radiation differing considerably in character from the primary producing it, were used as radiators, no variation in intensity of secondary radiation was observed as the bulb was rotated. This result was not found to be affected by a considerable variation in the penetrating power of the primary radiation.

Experiments were made with several X-ray tubes.—*Proc. Roy. Soc.*, lxxiv, 474.

II. GEOLOGY AND MINERALOGY.

1. *Plans for Obtaining Subterranean Temperatures.* — The recently issued Year Book, No. 3 of the Carnegie Institution of Washington, contains a report by G. K. GILBERT of the progress made in developing plans for an investigation of the subterranean temperature-gradient by means of a deep boring in plutonic rock. Mr. Gilbert discusses in detail the importance of such an investigation and the conditions that should be satisfied in the solution of the place for the boring. The conclusion is reached that an altogether favorable locality for the work is to be found in the Lithonia granite district in Georgia. In regard to this region in its applicability to the object in view, the author says :

“In its general topographic character the Lithonia district is a plain. The stream valleys, for the most part open, are excavated to depths of 50 to 150 feet. A few rounded bosses of granite project from 50 to 150 feet above the plain. The granite is surrounded and in part overlain by schists, which appear to have originally constituted the walls and cover of the batholithic chamber. The continuity of the granite mass from outcrop to outcrop is inferred from the close lithologic similarity found at all the outcrops. This similarity includes not only composition, but a peculiar and unusual structure, the granite having an imperfect schistosity, the planes of which are everywhere contorted. It is therefore called by the State Geological Survey *contorted granite-gneiss*. The rock is massive. Only a few joints were observed, and these appeared to be occupied by thin veins, and thereby sealed, so as not to affect materially the continuity of the rock. The partings utilized in quarrying are parallel to the surface and are usually not natural, but created by blasting. They indicate a tendency toward exfoliation, which is one of the characters of massive granite. In recent studies in the Sierra Nevada I have found the tendency to develop partings parallel to the

surface characteristic of massive rocks and absent from rocks traversed by systems of joints.

The extent of the granite body is not less than 10 miles in one direction by 3 miles or more in the transverse direction. Uniformity of character through such an area affords reasonable presumption that uniformity will be found in the vertical direction to such depths as are obtainable by the driller. The age of the batholith is not definitely known, but it is believed by students of Georgia geology to be probably pre-Paleozoic, and certainly not later than early Paleozoic. Of the later geologic history all that is demonstrated by the features of the locality is profound degradation, resulting in the development of a broad peneplain. Nothing is known in the vicinity of later orogenic or volcanic events, and the Cretaceous and Tertiary formations of the Coastal Plain are thought not to have covered this area. So far as is known, the region is one characterized by prolonged geologic quiet, and it has probably been exempt, as far as any locality which might have been selected in the United States, from physical and climatic accidents competent to disturb the arrangement of subterranean temperatures."

Besides the actual determination of the temperature-gradient, the conditions will be favorable for the prosecution of other investigations. The study of the core obtained would give valuable data as to the strength and physical properties of deeply buried granite. Further :

"It is at least worthy of suggestion that the boring could also be utilized for the subterranean swinging of a specially constructed pendulum, and the measurement of the earth's weight by means of a vertical pair of gravity determinations could thus be repeated. The homogeneity of the crust layer between the upper and lower stations and the representative character of the rock samples brought up as drill cores would be peculiarly favorable for the determination of the density of the crust layer.

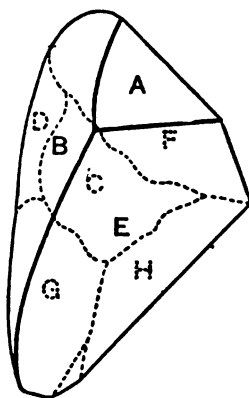
To give high precision to the determination of density it would be necessary to take account of the compression of the rock under stress of the superincumbent weight. Rock compression has not yet been measured in the laboratory, the matter being one of extreme difficulty, by reason of the deformation of both samples and testing apparatus when great pressures are applied ; but there is reason to think that valuable observations bearing on this point could be made within the boring at some stage of the work. It should be possible, by suitable automatic appliances, to measure that resilient elongation of the column of rock constituting a section of core which theoretically takes place while the drill is separating it from the general mass. The importance to geophysics of experimental determinations of rock compression is generally recognized."

It is much to be hoped that it may prove possible to go forward with this most important investigation. The expense would be large, of course, but for a depth of 6000 feet not prohibitory ; one estimate puts the cost of the boring at \$110,000.

2. *Vermont Geological Survey*; G. H. PERKINS, State Geologist. Annual Report, 1903-1904, 227 pp., 8 figs., 81 pls.—The fourth of the present series of Vermont State Reports indicates great activity on the part of Professor Perkins and his co-workers. In addition to a description of the present condition of quarry industries within the state, the report contains articles by Professor C. H. Hitchcock on the Glaciation of the Green Mountain Range, Professor V. F. Marsters on the Asbestos Deposits, and a paper by the state geologist on the Geology of Grand Isle County and the Brandon Lignite Deposit. Grand Isle County has been completely mapped in the past two years and the fossils have been studied. A special paper on the Stromatoceria of Isle LaMotte has been written by Professor H. M. Seeley. The origin of serpentine is discussed somewhat by Professor Marsters, who believes that magnetite may be shown to pass by imperceptible stages of decomposition into masses of fibrous serpentine. The interesting Tertiary deposits at Brandon are described and seven plates illustrating the fossil forms are published.

3. *The big "Cullinan" Diamond from the Transvaal*.—The April number of the Geological Magazine contains a description by F. H. HATCH and G. S. CORSTORPINE of the large diamond recently found in the Transvaal; from this we quote the following paragraphs. Two plates with four excellent views of the stone, natural size, accompany the paper but cannot be reproduced here.

"Great interest has been excited, not only in the Transvaal, but throughout the world, by the discovery at the Premier Mine, on Wednesday, the 25th January, 1905, of the largest diamond hitherto known. The stone was found by Mr. Wells, Surface Manager, in the yellow ground about 18 feet from the surface, a brilliant flash of light from a projecting corner having caught his attention. After a preliminary cleaning it weighs 3,024½ carats. According to Gardner Williams the South African carat is equivalent to 3.174 grains; consequently the diamond weighs 9600.5 grains troy or 1.37 lbs. avoirdupois. Through the courtesy of the Directors of the Company, we have been enabled to make an examination of the stone, with the following result: It measures 4 by 2½ by 2 inches. The stone is bounded by eight surfaces, four of which are faces of the original crystal, and will be referred to in this description under the letters A, B, C, D, and four are cleavage surfaces, the cleavage being of course parallel to the face of the octahedron. In the following description these cleavage surfaces are referred to under the let-



Diagrammatic projection
(to half scale).

ters E, F, G, H. They are distinguished from the original octahedral faces by greater regularity and smoothness. The shape and relative position of these various surfaces can be seen in the diagrammatic projection depicted in the text-figure, which has been drawn in the Mineralogical Laboratory of the Oxford University Museum, by the kind permission of Prof. Miers, F.R.S. The drawing is to half scale.

Description of the Surfaces.—A is an original octahedral face showing typical striations, the bands varying from 0.1 to 0.4 centimeter, and running parallel to the edge A-E. B is a large surface slightly curved showing partial striations, which, however, are interrupted by the slightly mammillary character of the surface. C is also a natural surface showing a few striations parallel to the edge C-E. D. Between B and F, C, G, there is an irregular octahedral face D, showing distinct equilateral triangular indentations which resemble etched figures, except in regard to their comparatively large size, the largest having a side measuring 0.7 centimeter. D is parallel to E.

E, F, G, H, are cleavage planes. E is the largest of these, and is a very perfect cleavage plane. Parallel to it within the crystal there is a small air layer between two internal cleavages, producing a 'rainbow' or Newton's rings. F is the second largest of the cleavage planes and shows a small spot within the crystal. G is an irregularly shaped cleavage plane. H is another cleavage face showing series of cleavages in the corner bounded by E and G. Two spots are visible, one actually on the surface, the other about 1^{mm} within the crystal. Of the faces given, A and G, H and B, and E and D are parallel. In the case of B and H the parallelism is imperfect owing to the curvature of B.

The purity of the crystal is best seen on looking into face E, and the luster is well seen on the irregular natural face B, the broken cleavage on H causing a good deal of refraction which affects B to some extent as the facets of a cut gem would. For a large stone the crystal is of remarkable purity, and the color approximates to that of a blue-white.

The large size of the cleavage planes E and F indicates that a very considerable portion of the crystal is wanting. From the shape of B, D, and G, one can say that the entire crystal was irregular in shape, but A and D being octahedral faces, the presumption is that the complete crystal was a distorted octahedron, probably with dodecahedral faces developed on the edges. The portions missing probably amount to more than half of the original crystal.

The Cullinan diamond, as it has been named, after the chairman of the Premier Company, is more than three times the weight of the largest diamond previously known—the famous stone found in 1893 at Jagersfontein in the Orange River Colony, which weighed 972 carats.

4. *Moissanite, a Natural Silicon Carbide*; by GEORGE FREDERICK KUNZ.*—Professor Henri Moissan, at a meeting of the

* Read before the New York Academy of Sciences, Jan. 9, 1905.

Academy of Sciences of Paris, held November 14th, 1904, read a paper on an examination made by him of a block of meteoric iron from Canyon Diablo, Arizona, which weighed 183 kilograms (403·6 lbs.).* Professor Moissan determined this mass to be somewhat heterogeneous in its structure, and to contain iron, nickel, sulphur, phosphorus, silicon and carbon. He found the latter element in its several forms,—amorphous carbon, graphite, and diamond,—and was able to separate both the black and the transparent variety of the diamond. He also discovered as absolutely new, in connection with these, green hexagonal crystals of silicon carbide. This is the substance which has been so extensively manufactured and sold commercially under the name of *carborundum*, and which, having a hardness of 9·5, above that of all minerals except the diamond, forms an admirable abrasive material for sawing gems, engraving glass, etc.

As this is the first instance in which this compound has been proved to occur in nature, and therefore, as a mineral, is entitled to a distinct mineralogical name, it would seem that the name of Professor Moissan himself should be associated with it. I would, therefore, propose for it the name of *Moissanite*, as a slight recognition of his many services to chemistry, and especially of his researches on the artificial carbides and his study of the constituents of meteorites, and the reproduction of similar substances by means of the electric furnace.

Photographs made by Professor Moissan show that the specimens isolated were entire crystals and must have been formed in the meteoric mass itself; they were not fragments such as were found by an American investigator a few years ago associated with fragments of corundum, which upon a careful search of the material he learned had been ground into the meteoric mass from the abrasive used in sawing the meteorite. No saws were used by Professor Moissan with the mass examined by him.

5. *Occurrence of Palladium and Platinum in Brazil.*—A very full and interesting paper upon this subject is given by E. HUSSAK in vol. cxiii of the *Sitzungsberichte* of the Vienna Academy (Abth. I). An exhaustive summary of the historical data is followed by an account of the author's own extended observations.

The metal *palladium*, in the native state, was discovered by Wollaston in Brazil a hundred years ago, being identified with native platinum in sands from gold washings, probably at Conceicao. The author failed to find the metal in the platinum sands of this locality, but he proved that it did occur in irregular grains (not rolled) of dark gray to steel-gray color with platinum and palladium-gold in the highly auriferous "Jacutinga"† of the itabirites of Itabira do Matto Dentro, Minas Geraes.

* *Comptes Rendus*, cxxxix, No. 20, cxl, No. 5, p. 277; also *Chem. News*, Dec. 14, 1904, Feb. 24, 1905; this *Journal*, xix, 191, 323, 1905.

† The name "Jacutinga" is given to the narrow layers and bands, hardly 50^{cm} in thickness, that occur interbedded conformably within the itabirite (a quartz-hematite rock of schistose structure). The Jacutinga are often enormously rich in gold, which may be nearly absent from the surrounding itabirite.

Palladium-gold, an alloy of the two metals in varying proportions, is not uncommon and the scales of "white gold" belonging here were noted as early as 1700 though at first supposed to be silver.

It occurs in the gold washings at various points in the states Goyaz and Minas Geraes. It is also found, with native platinum in the rock itself, thus in the "Jacutinga" at the Gongo Socco mine near Caethe Minas, at Itabira do Matto Dentro and at Maquine near Villa Marianna. It also occurs at Candonga, Minas Geraes, in a pyroxene rock which is probably derived from a limestone by contact metamorphism. This rock forms layers in the itabirite.

Platinum has been known to exist in Brazil for about one hundred years, but, previous to the identification of palladium, it was often confounded with the alloy palladium-gold. The explorations and investigations of the past thirty years have added largely to the number of localities of native platinum, which may be summarized as follows :

(a) It occurs sparsely disseminated through the highly auriferous Jacutinga, interbedded in the itabirite, as at Gongo Socco.

(b) In the auriferous quartz veins of the crystalline schists on the Rio Bruscius, Pernambuco.

(c) Associated with the less frequent diamond and probably derived from quartz conglomerates, on the east slopes of the Serra do Espinhaco from Itambe do Matto Dentro to Itambe do Serro.

(d) In the Rio Abaete and its left tributaries, here probably derived from olivine-rocks as in the Urals.

It is noteworthy that the platinum of occurrences (c) and (d) varies widely in composition ; that of Conceicao is non-magnetic and free from palladium with a specific gravity of 20.5 ; that from Condado is non-magnetic and rich in palladium, and that of Abaete is strongly magnetic and free from palladium, but rich in iron. The specific gravity of the platinum from Condado is from 15 to 15.5. The specific gravity of the metal from Abaete could not be determined because it was impossible to obtain the fine powder free from gold and perovskite.

In the occurrences (a), (b) and (d) the platinum seems to be a primary constituent, but in the remaining case, where it accompanies the diamond, it has so peculiar a form that a secondary formation is thought probable. Here the platinum appears not as rolled grains but in hollow forms, sometimes fern-shaped, with thin walls and mammillary or botryoidal, non-crystalline, surface; the structure is both concentric and fibrous. These forms are so unusual that a possible secondary origin is suggested, perhaps a deposit from solutions derived from the decomposition of sulphides carrying platinum. Such a formation the author regards as quite possible, since in the United States and Norway, ores of this kind (pyrrhotite, covellite, chalcopyrite) have been shown to carry platinum and to be associated with sperrylite ($PtAs_2$).

6. *Platinum Resources in the United States.* — The Geological Survey has undertaken the investigation of the resources of plati-

num in the country, having issued a circular giving information as to the nature and occurrence of the metal, and instructions as to sending samples, especially of heavy sands from placer mines, to Washington for thorough examination. A list is also given of the various localities, chiefly in California, Oregon, Canada and South America, in which platinum has been discovered, with indications as to which regions offer the most promise. It is to be hoped that this effort will result in developing the supply of the metal which is so much needed.

7. *Beiträge zur Mineralogie von Japan*; herausgegeben von T. WADA. No. 1. Pp. 1-21. Tokio, 1905.—The recently issued volume on "The Minerals of Japan" by T. Wada was noticed in the January number. The same author has also undertaken the publication of a series of contributions to the mineralogy of Japan, of which the first number is now in hand. This contains an interesting account by Kotora Jimbo of crystals of *danburite* of Obira, Bungo Province, with list of forms observed and angles measured. Another paper by the same author describes the *siliceous oolite* of Tateyama, Etchū Province. This oolite either consists of loose colorless spherules of opaline silica or forms a loosely coherent mass of colorless or gray spherules cemented by partly anisotropic colorless opal, or opal mixed with decomposed rock particles; the spherules are also found in loose form. Microscopic examination shows a concentric structure with a series of rings. These rings are in part nearly structureless and isotropic, in part fibrous and doubly refractive; the fibers are negative; between crossed nicols a black cross is obtained. The hardness of the spherules is about 6, the specific gravity nearly 2. They contain 93 per cent SiO_2 , and about 4 per cent loss on ignition. After ignition more than 80 per cent of the powder is dissolved in four hours in KHO with eight parts of water.

The deposit described occurs in connection with the small crater-lake of Shin-yu, 70 miles in diameter, and not far from the well-known hot springs of Tateyama. The lake is now filled with hot, gray, turbid water, from which abundant gas-bubbles issue; formerly the water is stated to have been cold.

The occurrence is one of much interest, since, as remarked by the author, it is the modern equivalent of the ancient springs of Pennsylvania described by various authors, among them Barbour and Torrey, see this Journal, xl, 246, 1890, also Wieland, *ibid.*, iv, 262, 1897; the latest investigation is by Diller, *Bull. U. S. G. Surv.* 159, p. 95, 1900. The spherules of Tateyama differ from those of Pennsylvania in their lower specific gravity, their less crystalline appearance and greater solubility in caustic potash.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences*.—The spring meeting of the National Academy was held at Washington, April 18 to 20.

Five new members were elected at the meeting: Arthur A. Noyes, Boston, Mass.; Michael I. Pupin, New York City; John

C. Branner, Stanford University, Cal.; William H. Holmes, Washington, D. C.; William H. Howell, Baltimore, Md.

The following foreign associates were also elected: M. Henri Becquerel, of Paris, and Prof. Dr. Paul Groth, of Munich.

The list of papers presented is as follows:

EDWARD L. NICHOLS: The mechanical equivalent of light.

Dr. H. C. WOOD and Dr. DANIEL M. HOYT: The effects of alcohol upon the circulation.

ALEXANDER AGASSIZ: The expedition of the U. S. Fish Commission Steamer "Albatross," in charge of Alexander Agassiz, in the Eastern Pacific, Lieut. Commander L. M. Garrett commanding.

WILLIAM M. DAVIS: Resequent valleys. The geographical cycle in an arid climate.

W. W. CAMPBELL: A catalogue of spectroscopic binary stars.

C. D. PERRINE: Discovery of the sixth and seventh satellites of Jupiter and their preliminary orbits.

W. K. BROOKS: The axis of symmetry of the ovaria egg of the oyster.

2. *Astronomical Observatory of Harvard College.*—Recent publications include the following:

ANNALS. Vol. LVI, No. II, Stars having Spectra of Class B.

Vol. LVIII, Part I. Observations and investigations made at the Blue Hill Meteorological Observatory, Massachusetts, under the direction of A. Lawrence Rotch. This part, of 62 pages, is devoted to a discussion by H. HELM CLAYTON of the diurnal and annual periods of temperature, humidity and wind-velocity up to 4 kilometers in the free air and the average vertical gradients of these elements at Blue Hill. Among other points of interest, it is shown that there is a rapid increase in wind-velocity from the ground to 500 meters, the rate being about twice as great in the night as in the day. From 500 up to 1000 meters, there is a slow increase in wind-velocity during the day but, in the average, a decrease by night. Above 1000 meters there is a steady increase of wind-velocity and the rate grows larger with increasing height.

CIRCULARS: No. 86, The nebula of Orion. No. 87, The ninth satellite of Saturn. No. 88, A new Algol variable— $15^{\circ} 4905$. No. 89, The November Meteors of 1904. No. 90, 105 new variable stars in Scorpius. No. 91, 16 new variable stars in Sagittarius. No. 92, Stars having peculiar spectra.

3. *The Journal of Agricultural Science*; edited by R. H. Biffen, A. D. Hall, T. H. Middleton, T. B. Wood, in consultation with W. Bateson, J. R. Campbell, W. Somerville. Vol. I, Part I, pp. 1-148. January, 1905. Cambridge (The University Press).—This new journal has been recently started to give an organ for the presentation and discussion of scientific papers bearing on agriculture. It is proposed to issue the Journal as material accumulates, in parts of about 100 royal 8vo pages; a volume will contain four parts. Subscription (\$4.50, single numbers \$1.50) may be made to the Macmillan Co., New York City.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLII.—*On a Group of Visual Phenomena depending upon Optical Errors of the Human Eye*; by CHARLES S. HASTINGS.

IN two preceding articles* the writer has contributed measurements which serve to define the average human eye, both with respect to its color error and its error of collimation, to a closer degree of approximation than that of Helmholtz and his successors as embodied in the well known *schematic eye*. The aim of this paper is to discuss certain consequences which may be based upon these more exactly determined data and to describe, and explain as far as practicable, a number of visual phenomena not thoroughly studied heretofore, or, perhaps, wholly known. For this purpose we require, in addition to the elements established in the papers cited, a knowledge of the positions of the external and internal pupils of the model eye. By the former term is meant the virtual image of the real pupil as formed by refraction at the cornea; and by the latter, the virtual image of the real pupil as formed by successive refractions at the anterior and posterior surfaces of the lens. These are evidently so related to each other that a ray from an object outside to a point in the exterior pupil will correspond to a ray from the corresponding point in the interior pupil to the image of the object. If we take, as in the preceding articles, the vertex of the cornea as the origin of coördinates, together with the place of the center of the real pupil as established in the second paper, a simple calculation shows that the centers of the pupils are at 0.3046^{cm} and 0.3705^{cm} , respectively, both lying on the nasal side of the axis

* This Journal, vol. xix, p. 205 and p. 310.

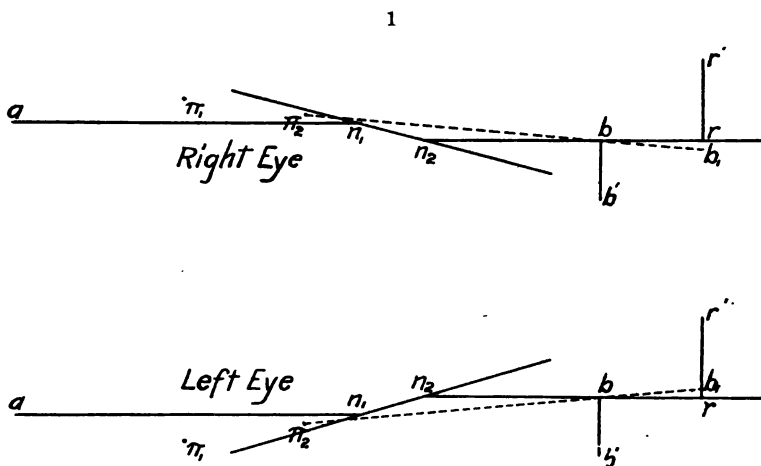
AM. JOUR. SCI.—FOURTH SERIES, VOL. XIX, No. 114.—JUNE, 1905.

of symmetry and approximately midway between these axes and the axes of vision. These values are for wave-lengths of mean refrangibility, the variations in the values for different wave-lengths not being of moment for our present purposes; the small difference in relative size of the two pupils is also ignored as immaterial.

The elements of the schematic eye, so far as they are necessary to our investigation, are:

	$\alpha = 4^{\circ} \cdot 2$	Dist. π_1 to $\pi_2 = 0.0659 \text{ cm}$
Dist. π_2 to $n_1 = 0.3264 \text{ cm}$		" n_1 to $n_2 = 0.0357 \text{ cm}$
" n_2 to retina = 1.55 cm		" F_b to $F_r = 0.0566 \text{ cm}$

These elements are represented in fig. 1, in which, for the sake of perspicuity, the scale is greatly distorted by increasing those



of the first column in the ratio of 2.5 to 1 and those of the second column in the ratio of 25 to 1. With this qualification fig. 1 represents accurately the necessary elements of a pair of normal eyes, the lines n_1, n_2 being the axes of the eyes, the lines a, n_1 the external, and n_2, r the internal lines of vision, and the points π_1 and π_2 the positions of the centers of the external and internal pupils, respectively. The points b and r are the positions of the images of a distant object on the line of vision for two wave-lengths of light corresponding to a difference of refrangibility in water of .0100, which corresponds to an interval in spectral colors nearly equivalent to that separating C and G.

I. *Utility of Error of Collimation.*

Suppose both eyes directed to a distant surface divided vertically into two portions of which the left side is red and the right blue, the point of fixation for each eye being on the line of demarcation. In this case the image of the red surface would be represented by the line rr' in each eye and that of the blue surface would be represented by the lines bb' , if the eyes were sharply focussed for red light, that is, if the retinas corresponded with the surfaces rr' , the observer would have a sharply defined image of the boundary in red and an ill-defined image in blue as the resultant effect of the diffusion circles due to the chromatic aberration of the eye. The diameter of these diffusion circles will bear the same ratio to the diameter of the interior pupil as the distance br does to $\pi_1 b$, while the centers of these diffusion circles corresponding to points at the boundary between the colored fields will lie on a line on the retina which is represented in the diagram by the projection of this line, namely, by the point where the line $\pi_1 b$ extended intersects the retina. It is obvious from inspection that only from the line $\pi_1 b$, towards the nasal side in the right eye, and towards the temporal side in the left eye, do we have a full illumination of the retina equal to that of the blue field itself. We see, therefore, that in the case supposed there is a narrow region, relatively dark, bordering the sharply defined edge of the red image in the right eye, while in the left eye there is a corresponding region where the contrast is reduced by a commingling of the two colored lights.

It is easy to see that if the eye is adjusted for distinct vision of the blue surface, that is, if the retina corresponds to bb' of the diagram, exactly the same conditions as regards sharpness of distinction hold as before. If the observer's attention were directed to this particular feature of the object, that is, to the dividing line in the field, he would inevitably accommodate either for the red or for the blue, and, ignoring the confused sensation of the left retina, recognize a sharpness of division which would be lacking if the right eye were symmetrical in construction. If the red and blue fields were interchanged the left eye would become the discriminating one.

Before we can attach great importance to this conclusion we must see if the relations quantitatively considered are such as to support it. To do this we must calculate the angular width of the darkened strip and of the radius of the diffusion circles; the first giving us a notion as to its conspicuousness as an interruption in the field of vision, and the second a notion as to its intensity. We read at once from the diagram that the true width of the region is—

$$\left\{ (n_1 - n_2)tg a + (\pi_1 - \pi_2)tg \frac{1}{2} a \right\} \frac{br}{\pi_1 b}.$$

If this quantity be divided by the distance from n_2 to the retina, we shall have its angular width. This is found to be equal to $1'$, a conspicuous magnitude, since alternate bright and dark lines of half this angular width can be distinguished under favorable circumstances.

The second part of the problem is not quite definite because the radius of the pupil is not a constant; but if we assume a diameter equal to 0.2^{cm} we shall be near the true value for ordinarily bright illumination. This assumption gives $6'.8$ for the angular value of the radius of the diffusion circles; in other words, this is the angular width of the strip within which the illumination of the retina by blue light falls from its maximum to zero. As experiment shows that a diminution of luminous intensity of less than one per cent is obvious at a sharply defined border, there is no room for doubt that the peculiarity of construction does possess a useful function in vision, inasmuch as that with the established collimation errors we are enabled to detect boundaries of colored fields with a degree of precision which would be wanting in eyes without such errors.

This is a highly interesting reason for the persistence of a systematic optical error in the human eyes which is otherwise extremely difficult to account for, since no other possible error admits of correction so easily. If we recognize the advantage which the peculiar relation of the collimation errors in the two eyes gives to one searching for colored fruits or colored animals, we may be led to the conclusion that in an earlier state of racial development the peculiarity would have been more important than at present, and then, perhaps, to speculation as to whether it may not now be regarded as largely vestigial. This last idea would doubtless find support in the extraordinary irregularity of the constant of collimation in the sixty or more cases recorded.

II. *Geranium Phenomenon.*

This is a name given provisionally to a peculiar visual phenomenon with which I have been familiar for an indefinite time, although it does not seem to have ever been noted, or at least recorded, by other observers. It is not unlikely that relatively few persons are able to see it, but it is not a personal peculiarity. Briefly described the phenomenon is this: When-

ever I look at red geranium petals, in the brilliant light of out of doors, projected against the more remote background of its green leaves, the petals seem—in portions of the visual field at any rate—to be bordered with an exquisitely fine line of intense blackness, much more intense than that of black velvet under the same illumination. My eyes cannot make these black lines point of fixation for they are singularly elusive, but they are too delicate to be seen if they did not fall very near the axis of vision. Red petals of other flowers exhibit quite the same phenomena, notably red nasturtiums, but only strikingly when the green background is sufficiently luminous.

The more important general conclusions from such observations seem to be embodied in the following list:

- (a) The phenomenon is monocular.
- (b) The dark lines are conspicuous only when the illumination is intense (equals, probably, when the pupillary aperture is small).
- (c) The contrasting colors must be well separated as regards refrangibility and of approximate equal brightness.
- (d) The difference of the distances of the two colored fields from the eye must not be small compared to the distance of the nearer one.

By attention to these precepts I have been able to observe the same phenomenon with a considerable range of pure spectral colors as well as to prove that the order of the colors, as measured from the eye, is not essential. The reason that I see the black lines as described above, and no black border to a green leaf projected upon a red petal, is to be ascribed, probably, to the fact that my slightly myopic eye can form a sharp retinal image of the red when not more than one or two meters distant, while the green leaf would be notably out of focus.

A highly probable explanation of this phenomenon can, I think, be found from an inspection of fig. 1 above. Suppose the parti-colored object be shifted so that the line of demarcation falls on the line n, π , extended; then, in the right eye, r and b , will have approached each other, but will still be distinct. Now imagine the blue portion of the object carried a considerable distance farther from the eye on the line n, π , extended, then light from points in the blue object very near its edge will send light to only the outer, or temporal, half of the pupil, the inner half being shaded by the nearer red object. It is, however, just this latter half of the pupil that transmits the light which diffuses blue light on the temporal side of the line π, b , hence there is a region of the retina between r and b , in the right eye, upon which, under the conditions considered, no light falls on any color whatever. No doubt such an

unilluminated portion of the retina, if it caused any visual perception, would be interpreted as a line of more than absolute external blackness.

In the case of the model eye the breadth of the dark band would be considerably less than one minute of arc and at a distance of about two degrees from the point of most distinct vision, hence it is perhaps doubtful whether it could be perceived as a black line. In the case of my own eyes the constant of collimation is about half that of the normal eye and the pupils are nearer the axis of vision. From these data we may estimate the angular value of $r b$, for my eyes, as something less than one half minute of arc at the *fovea centralis*. The value for the interval red-green may be regarded as half this value; and finally, at the eccentric position where the strip on the retina is wholly unilluminated this must be again reduced by an amount which could be determined accurately only when the constants of the eye are known with a greater precision than now attained. It is probable, however, that this value would not be less than ten seconds of arc. Whether a strip of the retina of a width only one sixth of the ultimate perceptual elements of vision would, when deprived of light, give rise to a conspicuous sensation, is a question which, as far as I can find, has not been considered by investigators in this field. It has been abundantly proved that the ultimate precision of optical definition, under the most favorable circumstances, is not less than $60''$; on the other hand, there is obviously no minimum limit for the angular width of a bright line for visibility, since this is only a question of the amount of light received by the eye, or of its brightness. But the question of how narrow a black line on a bright field can be seen is wholly different. My own experiments, although of great simplicity, seem to be perfectly adequate for our present purposes. I found that I could see a black hair of a measured diameter of 0.0025 inch as a black line, against a sky of favorable brightness, up to a distance of 300 inches. At the greatest distance the angular width is only $1''.72$. There is, therefore, no difficulty in adopting the above explanation of the phenomenon under discussion even if we were obliged to assume a much smaller value for the area of unilluminated retina.

A familiar example of this same phenomenon, if I am not mistaken, is presented to us by the appearance of a red billiard ball on a green table. Here the vertical contours of the ball are astonishingly sharp as compared to that of the upper surface, and also to what we might expect from the pronounced chromatic aberration of the eye.

III. *Phenomenon of "Fluttering Hearts."*

This phenomenon, upon which much has been written, is thus described by Helmholtz:—"A peculiar phenomenon, which perhaps belongs in the same domain as that of the flickering rotating disks, is that of the so-called fluttering hearts. On a colored sheet of stiff paper are placed figures of another vivid color; red and blue seem to yield the best results—the colors must be very vivid and saturated. If one looks at the sheet while it is moved to and fro with a certain quickness, the figures seem to move themselves and to shift forwards and backwards on their support. The cause of this appearance seems to depend upon the fact that the visual impression for different colors does not originate and die out with equal quickness, and consequently the blue appears left somewhat behind the red in the path described by the sheet."

Numerous experiments with a considerable number of observers made in accordance with this description proved wholly futile. Small disks of vividly colored paper scattered upon strongly contrasting grounds were tried under greatly varying circumstances of illumination and of observer without once succeeding. It was only after one of my colleagues brought me a particular book having green and black lettering printed upon a red cover, both colors being nearly saturated and of approximately equal luminosity, that the real phenomenon could be observed by me and exhibited to others. Even in this case it could not be recognized in a good illumination, either by day light or by artificial light, when the lighting was such that the texture of the surface and outlines of the green letters was well seen; but when illuminated by a single source of light, sufficiently remote so that the sharpness of the green letters was lost, the effect became absolutely startling—the green letters appearing to slip about among the black in a most unaccountable way. The astonishment shown by all to whom I have exhibited this optical illusion is a sufficient proof of its rarity in ordinary experience.

The indicated conditions of success in the experiment seem to be these:—

(a) The saturated colors must differ widely in refrangibility and not too widely in luminosity.

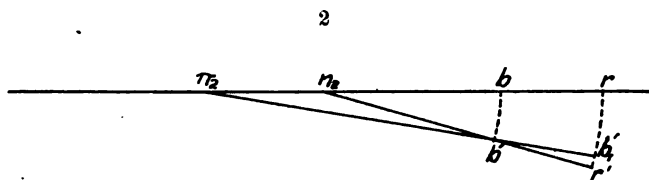
(b) The position of one of the colors in the visual field must be well determined—as by the sharply printed black letters in the object described—while the other must have its outlines ill defined.

With attention to these precepts I have been able to secure the illusion invariably with every one with whom I have experi-

* Helmholtz, *Physiol. Opt.*, 2te Aufl. p. 533.

mented. By isolating small pieces of colored paper by a black border from the red background I have been able to show the peculiar shifting in question for various hues of green, blue, and ultramarine blue. Sometimes when not obvious to direct vision it becomes striking to averted vision.

The explanation, it seems to me, may be found in the differing angular velocity with which the images of different colors move over the retina. This difference can be readily calculated in the following method.



Let the object move so that its image (fig. 2) in red light shifts its position from r to r' ; the corresponding image in blue light will shift from b to b' , while the center of the diffusion circle on the retina, supposed to be at r for convenience, shifts from r to b' . It is at once obvious that $rr'/bb' = n_2 r/n_2 b$; also $bb'/rb' = \pi_2 b/\pi_2 r$; whence $rr'/rb' = n_2 r \cdot \pi_2 b/n_2 b \cdot \pi_2 r$. From the table of dimensions given above this ratio is found to equal 1.0072; that is to say, when an object having red points is shifted in the visual field, the red points seem to have an angular velocity and an angular acceleration about three-fourths of one per cent greater than that of accompanying blue points. Thus, when the red surface described in the experiment is suddenly set in motion, the eye, for an instant fixed, judges of its acceleration and of the less acceleration of the green; then, following it in its motion until it is arrested, concludes that the more refrangible color is left behind—a false judgment which is corrected by the sense of a gradual approach of the green to its true position of rest, just as when the eyes, observing a procession of points passing fixed points, corrects a false judgment as to the place of the former, when the motion suddenly ceases, by an apparent temporary motion in the opposite direction. Of course, if we gain our notion of the angular velocity of the green areas from sharp visual perceptions of their boundaries, the illusion ought not to appear; it is only when the position of the colored area is recognized by its color alone that the effect becomes striking; hence the significance of faint illumination.

IV. *Binocular Color Relief.*

This is an optical illusion not noted in Helmholtz but described and studied at length by W. Einthoven, who was incited to the investigation by Donders.* According to this writer, Professor Donders was the first one to record the fact that red and blue objects in the same plane appear to most observers, when looked at with both eyes, to lie in different planes, especially when on a black background. To him, as well as to Einthoven, the red appears nearer than the blue. The explanation offered by Einthoven can be described by reference to fig. 1 above. Imagine both axes of the vision converged towards a red point which is accompanied by a blue point just above it: the red images would fall on the points of distinct vision, while the centers of the diffusion circles for blue would fall on disparate points of the retinas nearer the median plane, just where sharp images of a more distant red point would fall; hence the interpretation of the resulting sensation is that the blue point is in fact more remote. He finds evidence in favor of this view by the ingenious experiment of cutting off, by means of movable diaphragms in front of the eyes, first the inner halves of the pupils and then the outer; by this means he enhances or inverts the illusion. His experiments are easily repeated and are highly interesting.†

There are, however, serious objections to this explanation, not only as accounting for the observations, but also from theoretical considerations. Of about thirty individuals investigated Einthoven found that nearly one-third were not confident at first that there was any sensation of relief, while ultimately about half recognized the relief as did Donders, and the other half inferred an inverted order. This general conclusion is fairly well supported by my own more limited experiments. According to the theory, we are obliged to conclude that half of those investigated had the centers of their pupils lying on the nasal side of the axes of vision, and half on the temporal. It is, however, quite certain that a displacement of the pupil towards the nasal side of the axis of vision

* *Stereoskopie durch Farbendifferenz.* Graefe's Arch., xxxi (3).

† A convenient and interesting modification of this experiment may be made by observing a flat surface divided into separated areas of saturated colors through a binocular telescope of which the separation of the axes can be varied at will. The familiar prismatic binoculars are best adapted to the purpose, and any mosaic glass window in which the colors are vivid forms a far better object than colored pigments. If the axial separation is a little greater than that of the eyes, a striking relief will be observed in the sense described above, while a smaller separation will invert the relief.

is extremely rare ; consequently there seems to be no escaping the conclusion that similar visual impressions receive, not merely unlike, but opposite interpretations in different individuals. Any acceptable theory must adapt itself to this fundamental fact.

It seems to me that we can find a probable explanation in the following considerations. Imagine a number of red points distributed in two parallel planes which lie at right angles to their direction from the observer. If the eyes be fixed upon one of the points in the nearer plane, the images of all the other points in that plane will fall on pairs of congruent points of the two retinas, but the images of the points on the more remote plane, which will be quite sharp if the separation of the planes is moderate, will fall on disparate points of the two retinas. Now consider the case of red and blue points in a single plane. Here, if the eyes be fixed upon one of the red points, all the other red points will have their images on congruent points of the right and of the left retina, while the blue points, relatively very diffuse as compared to the images of the more distant red points in the former case, will fall on disparate points. So far there is a formal similarity between the two cases, but it cannot be carried further : in the first case a simple change of convergence of the axes of vision will change the disparate points to congruent, and *vice versa*, while in the second case no such change can produce such an effect ; but a change of accommodation proper to blue light will do so at once. The resemblances and differences are such, therefore, that it should hardly surprise us that certain persons recognize the second case as only a confusion of visual images, when others interpret the effect as a sort of chromatic relief ; nor is it astonishing that of the latter group, since there is really no fundamental relation between the two phenomena, some should imagine the red to be nearer than the blue points and others invert the order. It is singular, however, that Einthoven found those whom he observed to be distributed so nearly equally among the three classes.

The experiments of restricting the pupils by screens in front of the eyes is by no means conclusive ; indeed, it is questionable whether it has any bearing whatever upon the phenomenon. The screens will, primarily, increase very greatly the separation of the centers of the red and blue areas on the retinas which represent the images of the points ; moreover, the areas themselves will be much decreased. This will become evident from an inspection of fig. 1. But, as is easy to prove by a diagram, any lateral change of the common point of fixation will produce a relative change in the position of the colored areas on

the retinas, which can be compensated by an alteration in the convergences of the axes, and thus the phenomenon is reduced to one which admits of a simple stereoscopic interpretation in complete accordance with the observations. This is because such a shifting—whether produced by a change in the direction of vision or by a change of place in the object itself—partially uncovers one pupil while increasing the obstructed portion of the other, in short, virtually moves one pupil inwards and the other outwards. The resultant effect is like that produced by placing a thin wedge of glass before one eye, when the red appears in advance of the blue if the thicker edge of the wedge is on the nasal side; a reversal of the wedge inverts the apparent relief.

There is, however, one phenomenon which often gives a determining impulse to the interpretation in accordance with the experience of Donders, namely, the relative angular displacement of different colors upon the retina. Thus, in my own case, although quite unable to recognize anything like stereoscopic relief among a series of strongly colored figures on a black background when the eyes are fixed pretty steadily upon them, the relief appears very striking when I walk past it, or when the object as a whole is moved to and fro. So too, in the experiment of the fluttering hearts described above, although there is no chromatic relief under ordinary illuminations, such relief is an invariable accompaniment of the fluttering when produced. As has been shown above, the angular accelerations and angular velocities of moving objects in the visual field would vary with their color, so that colors of greater refrangibility would appear to change their directions from the observer more slowly, exactly imitating in this particular the effect of greater distance.

The illusion described would appear of rather abstract scientific interest were I not convinced that the incomparable French artists of the thirteenth century had recognized it and employed it for the purpose of artistic expression. Indeed, it was a casual inspection of the marvelous medieval windows in the great cathedral at Bourges which first turned my attention to the studies embodied in these papers, and which persuaded me that the one essential distinction between these antique windows and their unsatisfactory modern imitations lies in the knowledge, possessed by the old artists, of the effect gained by an ordering of their vivid colors so that the resulting chromatic binocular relief should fit the composition of their pictures. As far as known to me, the most beautiful surviving examples of this lovely art, as well as the most convincing support for the views here presented, are contained in that unapproached

collection; and not alone in the wonderful achievements of those forgotten artists, but also in the instructive failure which has attended modern restorations.*

This is not the place to suggest reasons why so charming an art should hardly have survived the thirteenth century, nor to discuss certain peculiar restrictions to which the artists subjected themselves; but were such an extension of this paper desirable, it seems to me that it would add material weight to the explanation, founded upon principles of physiological optics, of the acknowledged superiority of antique mosaic windows over their modern imitations.

*In two quadrifoils in the window given by the Guild of Tanners the artist has chosen a red background in place of the almost universal blue; but he has reversed the order of his colors throughout the composition so that the effect, to my eyes at least, was that of two charming little intaglios. It was this which first suggested to me the distinction between ancient and modern mosaic windows described above and which I thought abundantly verified by subsequent observations. Certain very puzzling contradictions to this theory—I have no means now of determining how many—were eliminated by a subsequent discovery that considerable areas of some of the windows are nineteenth century substitutions for the original designs which had been lost. There was no suggestion of this significant fact in my hands at the time of my visit.

Yale University, May, 1905.

ART. XLIII.—*On the Natural Iron-Nickel Alloy, Awaruite* ;
by GEORGE S. JAMIESON.

Two terrestrial iron-nickel alloys from adjoining localities will be described in this paper. One from Josephine Co., Oregon, which has already been investigated by Mr. W. H. Melville,* came through Mr. Maynard Bixby of Salt Lake City, Utah. The other, found at South Fork, Smith River, Del Norte Co., California, was from Dr. David T. Day, Chief of the Division of Mining and Mineral Resources of the United States Geological Survey. Both specimens had been sent to Professor S. L. Penfield, at whose advice this investigation was undertaken.

The specimens from Josephine County were water-worn, bean-shaped pebbles, varying in size from a few millimeters to two centimeters in diameter and were composed not only of the alloy, but also of more or less siliceous matter. Thin sections showed that the alloy was of a spongy nature, binding together and enclosing particles of silicate, which had the appearance of serpentine and gave the chemical reactions for that substance. In a steel mortar, the pebbles were easily broken into a powder and no mechanical method of making a separation of the metal from the serpentine seemed possible. A chemical separation, however, was easily effected by treating the powder with water and iodine at ordinary temperature. A complete solution of the alloy was thus obtained in about a day, while the siliceous matter was not dissolved by this treatment. The insoluble silicate was filtered on asbestos, air dried, and weighed. Duplicate analyses were made with the following results :

Insoluble silicate	24.15	24.55
Iron	19.17	18.95
Nickel	56.30	56.07
Cobalt .....	.35	.35
Phosphorus .....	.04	.04
Sulphur .....	.09	.09
	<hr/>	<hr/>
	100.10	100.05

Deducting the insoluble silicate and recalculating the remaining constituents to one hundred parts, the following percentages were obtained :

Iron	25.24	25.11
Nickel	74.17	74.30
Cobalt .....	.46	.46
Phosphorus .....	.04	.04
Sulphur .....	.09	.09
	<hr/>	<hr/>
	100.00	100.00

* This Journal [8], xliii, 509.

These results differ but slightly from those obtained by Melville, who found iron 23·22, nickel 60·45, and 15·83 per cent of other constituents. The metals calculated to 100 per cent equal, iron 27·75, and nickel 72·25.

The sample of iron-nickel alloy which came from Smith River, California, was in the form of grains of remarkably uniform size, about 0·15 millimeters in diameter, with an occasional larger grain, up to 1·5 millimeters. The metallie sand, for that is what it appears to be, was obtained from gold washings and was chiefly composed of the alloy, but mixed with magnetite, and a very little chromite. As no mechanical method for separating the alloy from the magnetite seemed to give satisfaction, a separation by chemical means was again resorted to. The size of the grains, which could not be reduced to powder, made the solution in iodine altogether too slow for practical purposes. The alloy was found, however, to be easily soluble in warm dilute nitric acid (one part conc. HNO_3 : two parts H_2O), while the magnetite was not appreciably attacked, if at all. Duplicate analyses were made with the following results:

Insoluble matter	9·45	9·97
Iron	19·21	18·97
Nickel	68·61	68·46
Cobalt	1·07	1·07
Copper	·59	·56
Sulphur	·05	·05
Phosphorus	·04	·04
Silica	·10	·19
Magnesium oxide	·50	·44
	<hr/> 99·62	<hr/> 99·75

The specific gravity was found to be 7·45 or, allowing for 9·7 per cent of magnetite, the value 7·85 is obtained for the alloy.

Deducting the insoluble matter, consisting of the magnetite, a small amount of chromite and the traces of silica and magnesium oxide, and recalculating the remaining constituents for one hundred parts, the following percentages were obtained:

Iron	21·45	21·28
Nickel	76·60	76·79
Cobalt	1·19	1·20
Copper	·66	·63
Phosphorus	·04	·04
Sulphur	·06	·06
	<hr/> 100·00	<hr/> 100·00

In dissolving the alloys in hydrochloric acid, it was noted that there was no odor of hydrocarbons, such as is observed when iron and steel are dissolved, nor was there any evidence of graphitic carbon.

These two iron-nickel alloys are quite similar in composition to those which have already been described from other localities, and for comparison, a table has been arranged to show percentages of iron and nickel which these various alloys contain. The first analysis is that of an alloy found at Gorge River, which flows into Awarua Bay on the west coast of South Island, New Zealand, described by W. Skey* in 1885 and to which the name awaruite was given. The second analysis, by A. Sella,† is of an alloy from the gold-bearing sand of the Elvo River, near Biella, Piedmont, Italy. The third analysis, by Melville, is of material from Josephine Co., for which the name Josephinite was suggested. No. 4 is a recent analysis by F. G. Wait, quoted by G. C. Hoffmann,‡ of a similar alloy from Fraser River, British Columbia, to which Hoffmann has given the name souesite, as stated by him, "to distinguish this find from that of other naturally occurring iron-nickel alloys." The last two analyses are those of the present writer.

Locality.	Analyst.	Fe.	Ni.	Co.	Cu.	Other constituents.
1. New Zealand	Skey	31·02	67·63	·70	none	·63
2. Piedmont, Italy	Mattiolo	26·60	75·20§	--	none	--
3. Josephine Co.	Melville	27·41	71·35	·65	·59	--
4. British Columbia	Waite	22·30	76·48	none	1·22	--
5. Josephine Co.	Jamieson	25·24	77·17	·46	--	·13
6. Del Norte Co.	"	21·45	76·60	1·19	·59	·10

It is seen from a glance at the analyses of the alloys from the five different localities, that there is a certain uniformity in composition, but that they are not a definite compound of iron and nickel is evident, nor would this be expected; with Fe:Ni = 1:3, the percentages are Fe 24·00 and Ni 76·00, to which most of the analyses approximate, while for the ratio 1:2 the values are Fe 32·19 and Ni 67·81. It seems unfortunate that so rare a substance should have received three distinct names, awaruite, josephinite, and souesite, and it is urged that awaruite, which has priority, should alone be used.

As regards the occurrence of the alloy, its association at Josephine Co., Oregon, with serpentine, and at New Zealand, Piedmont, Frazer River, and Del Norte Co., Cal., with chromite, suggests that it is a material which has separated from basic peridotite rocks, and, as it seems to have no tendency to deteriorate by oxidation, it is found as a heavy constituent in adjacent river sands.

In closing, it is desired to thank Mr. Bixby and Dr. Day for the material which they had sent to the laboratory for investigation, and also Professor S. L. Penfield for his help and valuable suggestions.

Sheffield Scientific School of Yale University, May, 1905.

* Trans. N. Zeal. Inst., xviii, 401.

† Comp. Rend., cxii, 171.

‡ This Journal (4), xix, 319, 1905.

§ Contains cobalt.

ART. XLIV.—*Hyopsodidæ of the Wasatch and Wind River Basins*; by F. B. LOOMIS.

DURING the early summer of 1904, Amherst College sent a party into the Wasatch along the Big Horn River, where an unusually complete collection was obtained: later, collecting was continued in the Wind River beds, a new and rich locality having been found on the east side of Bridger Creek, about ten miles northwest of Lost Cabin Post Office, Wyoming. In the latter basin, the fauna of which has been but meagerly known, some 400 specimens, distributed among about 50 species, were found. As a large number of the species are new, the material, together with that of the Wasatch, has been used in a study of the families represented; reference also having been made to other collections from these horizons, especially those of Cope and the American Museum of Natural History, both being in that museum.

Order INSECTIVORA.

Family *Hyopsodidæ*, Schlosser.

This family as now known includes two genera, *Hyopsodus* and *Sarcolemur*, both from the North American Eocene. The genera were originally classed among the Primates; and so in Cope's* and Osborn's† papers are placed under the suborder Mesodonta; or by Schlosser‡ under the equivalent Pseudolemuroidæ. Wortman,§ however, has classed them among the Insectivora, giving the following reasons: 1, the incisors are 3/3; 2, the tympanic bulla is not ossified; 3, the structure of the molars is not Primate; 4, the enterocarotid circulation is that typical of the Insectivora; 5, the limb bones differ from those of any known Primate; 6, the metapodials are not Primate; 7, the phalanges are short; 8, the hallux is not opposable. The writer too would place the *Hyopsodidæ* among the Insectivora and in the neighborhood of the genus *Erinaceus*.

The family may be defined as follows: teeth in a continuous series, cusps more or less pointed; superior molars with intermediate cusps (protoconule and metaconule); posterior internal cusp (hypocone) less developed than the other cusps; the lower molars with a low anterior buttress (protolophid) connecting the two anterior cusps; a second buttress behind the first, connecting the same cusps posteriorly (metalophid) more or less developed; the entoconid feebly developed (see fig. 1).

* Rep. U. S. Geol. Surv., iii, 738, 1884.

† Bull. Amer. Museum Nat. Hist., 178, 1902.

‡ Die Affen, Lemuren, Chiropteren N. S. W., 21, 1890.

§ This Journal, xv, 400, 1903.

Two genera are distinguished by Cope and Osborn on the condition of the metaconid: when simple, *Hyopsodus*; if bifid, *Sarcolemur*. The two genera are certainly distinct but further characters are required to separate them; for several jaws, which, in all other features, are most closely related to *Hyopsodus*, still have the metaconid bifid. This character has also been noticed as occurring in the genus *Eohippus*, *Phenacodus*, and *Systemodon*, and is not, therefore, considered alone enough to separate the two genera. The bifid metaconid is used below to distinguish some of the species of *Hyopsodus*.

Hyopsodus is characterized by lower wider teeth, the cusps being blunter; the fourth premolar is wide and not compressed, having fewer and less developed cusps. It occurs in the Wasatch, Wind River and Bridger horizons. In several species there is a tendency to have the metaconid bifid, but it is never as marked as is characteristic of *Sarcolemur*.

Sarcolemur is characterized by narrow trenchant teeth, with pointed cusps; the fourth premolar is much compressed and has the anterior cusps well developed. It is as yet known only from the Bridger, and of the promolars only the fourth is known.

HYOPSODUS Leidy

Lemuravus Marsh, *Stenacodon* Marsh, *Microsus* Leidy, *Diacodexis*, Cope.

The genus was founded by Leidy* on an imperfect lower jaw of *H. paulus* from the neighborhood of Ft. Bridger. The name *Microsus*† was given the same year to a second species differing only in the proportionate depth of the mandibular ramus. *Stenacodon*‡ was founded by Marsh on what proves to be a last lower molar, the genus being separated on the ground that there was no cingulum. *Lemuravus*§ was proposed for a species on the basis of the incisor formula being 3/3 which, later, proved to be true for *Hyopsodus*. *Diacodexis*|| was proposed by Cope for a specimen, including premolars of *Eohippus*. As yet the only members of the family found in the Wasatch and Wind River horizons belong to the genus *Hyopsodus*, the skeletal features of which are as follows:

The skull is elongate with a level top terminating abruptly behind, the rear of the cranium overhanging the occipital condyles, somewhat as in Rodent skulls. The zygomatic arches are slender but widely arched. On the deep lower jaw, the anterior border of the surface for attachment of the masseter

* Proc. Acad. Nat. Sci., Phila., 110, 1870.

† Same cit., p. 113.

‡ This Journal, ii, 210, 1892.

§ Same cit., vol. iv, p. 239, 1875.

|| Proc. Amer. Phil. Soc., vol. xxi, 181, 1883.

muscle lies just under the last molar. The teeth are in a continuous series but without crowding. In the upper jaw, the hypocone of the last molar is merely a rudiment, indicated by a slightly raised portion of the cingulum. Molars one and three have a small but distinct hypocone, the cingulum running to it. The first and second premolars have a single cusp while the third and fourth each have inner cusps. The canines are moderate and the three incisors simple. Specific characters are found only in the cingulum and size of the form. The lower teeth are more varied, especially the last molar. The general topo-

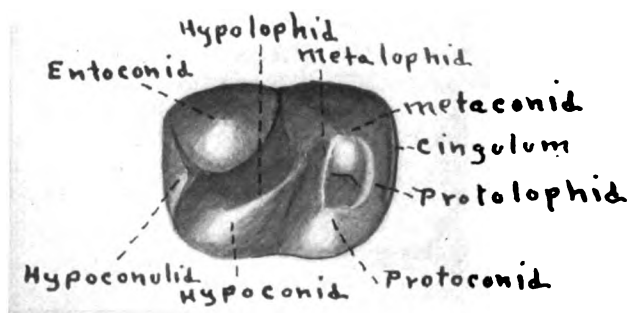


FIG. 1. A typical *Hyopsodus* lower molar. \times nat. size.

graphy of a lower tooth with the nomenclature here used is given in fig. 1. On the front part of the tooth the protoconid and metaconid are the principle cusps, connected anteriorly by a low curved protolophid. The inner end of this is in some species developed into a tiny cusp, the possible equivalent of the paraconid. Behind, these same two cusps are usually united by a metalophid, and the hypoconid is connected to the metaconid by a more or less developed ridge (hypolophid). The entoconid is always feebly developed, and between it and the hypoconid there is a strong hypoconulid. The fourth premolar has the protoconid and deutoconid well developed, and from the former a ridge runs to the front, while a second ridge runs from the same cusp to the rear, developing in some species one or two cusps on the margin. The third premolar is similar but simpler.

Of the milk dentition I have seen nothing which is worthy of note among so many specimens.

The skeletal material, while rather fragmentary, gives many of the characters which determine the ordinal position of genus. The stout humerus is widened at the distal end and pierced by a supratroclear foramen (similar to *Erinaceus*).

The olecranon process of the ulna is long (distinctly an Insectivor character), and the greater sigmoid cavity is very wide, the less sigmoid cavity being also well marked. The femur is short, thick and flattened, and has a strong third trochanter. (This is not found in Primates, but is especially well marked in *Erinaceus*.) Finally, according to Wortman, the metapodials are short and stout, and the hallus not opposable (both Insectivor features).

Hyopsodus simplex sp. nov.

The specimens of this, the smallest and at the same time most abundant of the Wasatch species, were referred by Cope to *H. vicarius* and *H. paulus*, both of the Bridger horizon. Osborn* provisionally referred them to *H. miticulus* Cope, from the New Mexico Wasatch, but differing from *H. simplex* in being somewhat larger and having a low ("Esthyonyx-like") heel and in having the posterior cusps more developed.

For a type, a lower jaw of the left side carrying the fourth premolar and the molars is chosen. All the teeth of the lower jaw are short and wide with obtuse cusps. On each there is a trace of a cingulum about the rounded anterior outer corner of the tooth and also externally between the cusps. On the wide fourth premolar the protoconid is better developed than the deutoconid, and behind there is a wide basin, the posterior margin of which is crenulated. On molars one and two the protolophid is well developed, while there is not more than a trace of a metalophid. A strong ridge runs from the hypoconid to the metaconid. The entoconid is weak and has a small tubercle in front of it, very characteristic of the species. On the last molar the heel region consists of a basin bounded behind by a high crenulated rim, on which the hypoconulid and entoconid appear as crenulations, scarcely larger than the others.



FIG. 2. *Hyopsodus simplex*. Left ramus. $\times \frac{1}{2}$.

Each of the upper molars has the cingulum in front, outside and behind. The last of these molars is much reduced and is without a true hypocone. Promolars three and four have each an internal cusp, while the front two are simply cusps.

Affinities—*H. simplex* is about the same size as *H. vicarius* from the Bridger, but the molars are shorter and more robust, while the hypoconulid is less developed and has an extra tubercle in front of it. *H. paulus* is a much larger and better developed species. *H. miticulus* is the nearest form, the more specialized and low talonid, and the superior size distinguishing it from *H. simplex*.

* Bull. Amer. Museum Nat. Hist., xvi, 183, 1902.

Locality—27 specimens were collected from both the upper and lower beds of the Wasatch on Gray Bull River.

They run very uniform in size, the length of the three lower molars being between 10 and 11^{mm}. In a few cases the last lower molar was considerable smaller than the normal.

Hyopsodus miticulus Cope.*

This form from the New Mexico Wasatch is thus described by Cope: "Parts of several specimens of this species show that the molars are similar in size to *H. paulus*, but that it has a much smaller last inferior molar, which has such a low heel as to resemble the corresponding tooth of the species of *Esthonyx*."

The species seems to resemble *H. simplex* most, but is larger and differs in the heel being low, and more developed. The last molar is also proportionally smaller. The two cannot in the writer's opinion be included in one species.

Hyopsodus lemoinianus Cope.†

This species presents several difficulties on account of the large amount of variation in size, and in the development of both the metaconid and the metalophid; but in as much as these variations do not seem to be constant, and as intermediate forms are found between the widest variations, all these related forms have been assigned to the one species. *H. lemoinianus* was established by Cope, who figured a left ramus with the molars, on which the metaconid is but slightly bifid. Osborn figures a second specimen with the metaconids also but little twinned. Most of the Amherst specimens have this cusp markedly bifid, as is seen in the specimen figured.



FIG. 3. *Hyopsodus lemoinianus*.
× $\frac{1}{2}$.

The species may be described as follows: There is a cingulum on the front of the tooth, and between the external cusps of the moderately stout teeth. On molars one and two, there is developed on the inner end of the protolophid a small but distinct paraconid, which makes the metaconid appear bifid. The metalophid is either entirely wanting or but moderately developed. The entoconid is small, as is also the hypoconulid. The last lower

molar is longer, and similar except that the hypoconulid is developed into a prominent heel. On the upper molars the cingulum is well marked and the cusps fairly high.

The three lower molars measure 13 to 15^{mm}, there being considerable variation in size. The nine specimens collected all occurred in the basal beds along the Gray Bull River, Wyoming.

* Rep. Vert. Fossils of New Mexico, Appen. F.F., Rep. Chief. Eng., 8, 1874.

† Proc. Amer. Phil. Soc., xx, 148, 1881.

Hyopsodus powellianus Cope.*

This, the largest species of the *Hyopsodidae*, occurs but infrequently, being known by parts of the lower jaw only. The teeth are low and wide with stout, low cusps and no cingulum. The metaconid is simple and widely separated from the protoconid. The hypoconulid is small, even on the last molar. The protolophid is low and the metalophid lacking. On the last molar the entoconid region is occupied by two small cusps.

FIG. 4. *Hyopsodus powellianus*. $\times \frac{1}{2}$.

The three lower molars measure together 18^{mm}. In the Amherst collection the species occurs but twice, both specimens coming from the basal beds of the Wasatch of the Gray Bull River, Wyoming.

Hyopsodus laticuneus Cope.†

A single specimen represents this species, on which the genus *Diacodexis* also hangs. The specimen included both upper and lower teeth, but Matthew has removed the lower premolars and assigned them to *Eohippus index*, leaving the upper molars which are characteristic of the genus *Hyopsodus*, and a last lower molar which is distinguished by low broad crown with obtuse cusps, lack of an external cingulum and the entoconid region occupied by two small cusps, and lastly by the metaconid being bifid. This last character alone distinguishes the species from *H. powellianus* to which it is equal in size. The specimen came from the Wasatch in the neighborhood of Gray Bull River.

In the Wind River horizon, four species are known, three of which are here described for the first time. This horizon is marked by a slight advance in the development of the genus. The hypoconulid is stronger, especially on the last molar, and in the entoconid region there is only a single strong cusp, the entoconid. The metalophid is universally present.

In the locality found by the Amherst party the specimens of *Hyopsodus* formed fully a third of the collection.

Hyopsodus wortmani Osborn.‡

The type specimen (including an upper and a lower jaw) was first figured by Cope among *H. vicarius* specimens, and was later by Osborn removed and used as the type of this species, the description however being very meager.

The teeth are moderately wide with rather low cusps and a cingulum along the front only. On the fourth premolar the protoconid and deutoconid are connected by a sharp ridge; the basin behind is wide, and on the outer side of the rim is a

* Rep. U. S. Geol. Surv., iii, 235, 1884.

† Proc. Amer. Phil. Soc., xx, 181, 1881.

‡ Bull. Amer. Museum Nat. Hist., xvi, 185, 1902.

small cusp. The protolophid and metalophid are both well developed on the first and second molars but on molar three the latter is very weak. The hypoconulid is small on the first two molars but developed into a prominent heel on the last, the entoconid being tiny. The upper molars are those typical of the genus, having a cingulum in front, outside and behind.



FIG. 5. *Hyopsodus wortmani*. $\times \frac{2}{3}$.

The specimens run uniform in size, the three inferior molars measuring 12mm. On Bridger Cr., 37 specimens were collected and the species occurs also in the other Wind River localities.

Hyopsodus minor sp. nov.

Though but one example of this tiny form was found, it differs so materially from *H. wortmani* that it is impossible to include it in that species. The type specimen is part of the right ramus with the three molars measuring together 10mm.

The teeth are short, with obtuse but well-separated cusps, and have a cingulum in front and a trace of it between the external cusps. The proto- and meta-conids are set close



FIG. 6. *Hyopsodus minor*. $\times \frac{1}{2}$.

together and united by both a protolophid and metalophid. The hypoconid has a strong ridge running to the metaconid, while the hypoconulid and entoconid are both strongly developed.

The species is distinguished by its small size, presence of a cingulum externally and the strength of the ento- and hypoconulid. The locality is Bridger Cr., Wyoming, in the Wind River horizon.

Hyopsodus browni sp. nov.

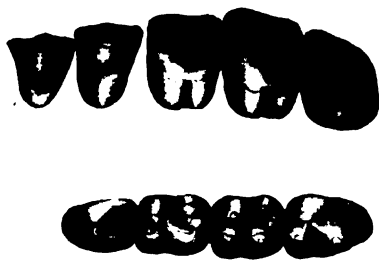
This, the most abundant species in the Wind River beds, is named in recognition of the successful work of Mr. T. C. Brown in collecting these forms. The type is a left ramus with the molars and fourth premolar; while an upper jaw with premolars three and four is associated with it as co-type. A less complete specimen has both upper and lower dentition.

The teeth of the lower jaw are short and stout with obtuse cusps, and a cingulum along the front only. On the fourth premolar the deutoconid is merely indicated by a small cusp, and behind on the proterior margin of the basin, there is a small external cusp. On all the molars the proto- and meta-conids are set close together and united by both a proto- and meta-lophid. The hypoconid is large and connected the metaconid by a wide ridge. The hypoconulid is rather large on all the molars but does not make a strong heel on the third molar.

The upper molars have a cingulum in front, outside and behind; on the which, where it meets the ridge from the para-

cone, there is a strong parastyle. The protoconule is closely united to the protocone. The last molar is large, but still lacks the hypocone. The third and fourth premolars have the parastyle but lack the intermediates and hypocone.

The species includes the medium sized individuals of the Wind River, the three lower molars measuring 15^{mm}. It compares in size to *H. lemoinianus* but lacks the external cingulum, and has a simple metaconid as well as having much more obtuse cusps. There are 45 specimens in the Amherst collection all from Bridger Cr., Wyoming.

FIG. 7. *Hyopsodus browni*. $\times \frac{1}{2}$.

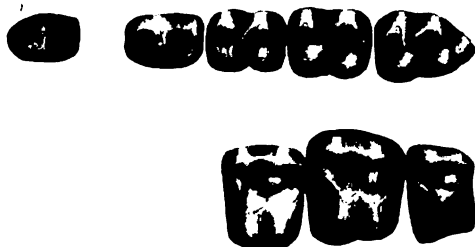
Hyopsodus jacksoni sp. nov.

In many ways this is the most specialized of the *Hyopsodidae*, and it has been named in recognition of the interest and coöperation of Mr. E. E. Jackson in the Amherst expeditions. The type is a right ramus with the molars and the fourth premolar, and a third premolar from the left side. The co-type contains three upper molars.

The lower molars are rather narrow with moderately high cusps and a cingulum along the front side

only. The metaconid is bifid, strongly so on the first molar, and just visibly so on the last. The protoconid and metaconid are widely separated and connected by the protolophid only. The hypoconulid is throughout small; and on the third molar connected by a ridge to the entoconid. The fourth premolar is complex, the protoconid and deutoconid being connected by a ridge; and there are two well-developed cusps behind on the posterior rim. The third premolar is similar but lacks the two posterior cusps. The upper molars are those typical of the genus, with the cingulum well developed on the outside. A distinct parastyle is formed on the anterior external angle of the cingulum. The posterior intermediate is isolated while the anterior one is connected to the protocone.

The three lower molars measure together 16^{mm}. 26 specimens were found along Bridger Cr., Wyoming.

FIG. 8. *Hyopsodus lawsoni*. $\times \frac{1}{2}$.

Lower premolar 4	Deuteroconid strong: posterior margin of basin crenulated without cusps	Deuteroconid strong and bifid: posterior margin of basin with two tiny cusps	Deuteroconid smaller than protoconid: connected by ridge: posterior margin with external cusp	Deuteroconid connected to protoconid by ridge: posterior margin with two cusps
Lower molars 1 & 2	External cingulum, traces: hypoconulid large: no metalophid: entoconid with tubercle in front: metaconid simple	External cingulum, traces: hypoconulid strong: no metalophid: entoconid medium simple: metaconid bifid	No external cingulum: hypoconulid small: metalophid: entoconid small: metaconid simple	No external cingulum: hypoconulid large: metalophid: entoconid medium: metaconid simple
	No external cingulum: hypoconulid medium: no metalophid: entoconid simple: metaconid simple	No external cingulum: hypoconulid small: no metalophid: entoconid medium simple: metaconid bifid	No external cingulum: hypoconulid small: metalophid: entoconid small: metaconid simple	No external cingulum: hypoconulid large: metalophid: entoconid medium: metaconid simple
Lower molar 3	External cingulum, traces: metaconid simple: entoconid with a small tubercle in front: heel not prominent	External cingulum, traces: metaconid bifid: entoconid with a small tubercle in front: heel prominent	No external cingulum: metaconid simple: entoconid with a small tubercle in front of it: heel prominent	No external cingulum: metaconid simple: entoconid with a small tubercle in front of it: heel prominent
	No external cingulum: metaconid simple: entoconid with a small tubercle in front: heel not prominent	No external cingulum: metaconid simple: entoconid with a small tubercle in front of it: heel prominent	No external cingulum: metaconid simple: entoconid with a small tubercle in front of it: heel prominent	No external cingulum: metaconid simple: entoconid with a small tubercle in front of it: heel prominent
Length of 3 lower molars	10-11 mm	18-15 mm	12 mm	16 mm
Horizon	Wasatch	Wasatch	Wind River	Wind River
	27	9	37	45
No. of specimens	27	9	37	45

ART. XLV.—*Some Results of late Mineral Research in Llano County, Texas*; by WILLIAM E. HIDDEN.

THE noted gadolinite locality in Llano County, Texas, known as Barringer-Hill, was reopened* and thoroughly prospected by the writer, during the winter of 1902-03, with very encouraging results. All the old cuts were cleaned out and extended, and a systematic development of the mine was begun at the southeast point of the hill, and at as low a level as the river terrace would permit. The plan was to remove the hill by blasting and gradually make a dump of

1



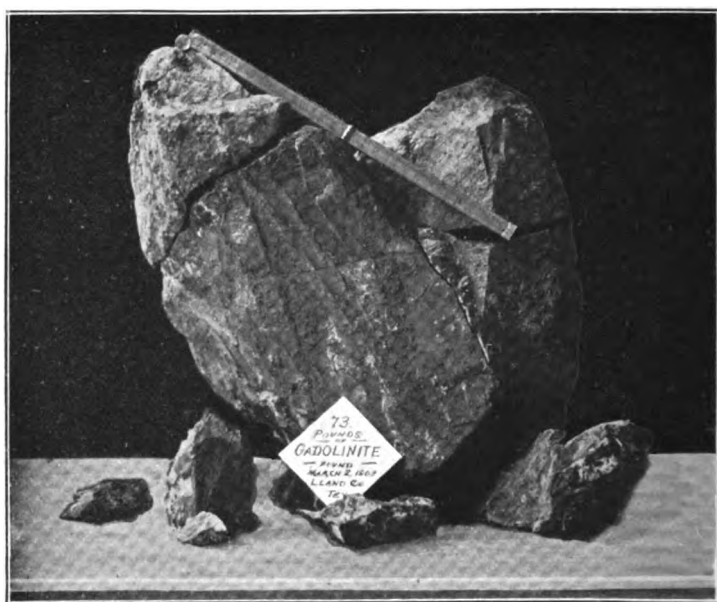
73-lb. mass of Gadolinite in place.

it towards the near-by Colorado river. The season proved to be a very propitious one and much good work was accomplished. Seven years had elapsed since any work had been done upon the property, but in a short time all the old familiar minerals had been rediscovered either in new openings or in extensions of the original workings of Mr. Barringer.

* The development was undertaken under the auspices of the Nernst Lamp Company, of Pittsburgh, Pa., to whom all the output was sent.

Among the most notable discoveries of "Barringer-Hill" minerals, at this time, were the double crystal of gadolinite that weighed seventy-three pounds and an eighteen-pound mass of yttrialite (see figures 1, 2 and 3); a mass of pure allanite that weighed over three hundred pounds; about fifty pounds of thoro-gummite, among which were pieces weighing fully a pound and some few good crystals. Of fergusonite several very pure masses and large aggregations of rough crystals were found, up to five pounds in weight. Of rowlandite one very pure mass weighing just one kilo was obtained; of nivenite and mackintoshite very little was discovered. The mineral

2

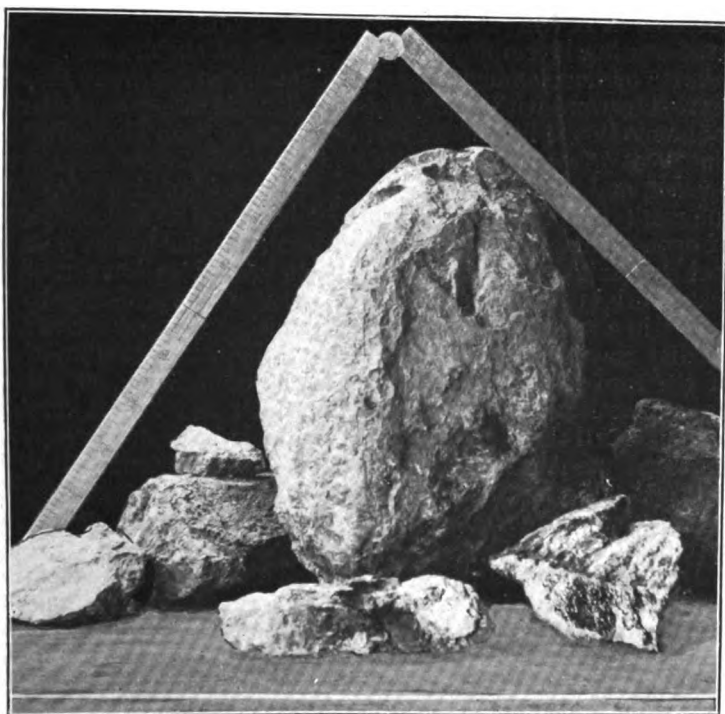


species rich in yttrium-erbium were more particularly sought after because thorium and uranium were not used in the "glower" of the Nernst Lamp.

Masses of coarsely crystallized fluorite up to four hundred pounds weight were not rare, and some of these had very large faces of the cube and rhombic dodecahedron. Its color varied from dark green to puce and purple, and colorless transparent rough crystals having remarkably perfect cleavage were sometimes observed. Some of the fluorite was true chlorophane and exhibited a brilliant green light when strongly heated and viewed in the dark. One mass was self-luminous, at night,

without heating it. Enormous crystals of orthoclase were common, some over five feet in diameter. Quite frequently small veins of very perfect red feldspar crystals (highly-twinned), and upon which albite crystals were attached, were found bordering the fluorite and penetrating it. In the feldspar, well crystallized menaccanite was sometimes observed, and this mineral is new to the locality. Yellow rutile, of the sagenitic variety, was observed in only one instance and then upon smoky quartz crystals. Polycrase, or an allied species,

3



18-lb. mass of Yttrialite.

was seen implanted upon the gadolinite, this is also new to the region. A cavity into which a horse could have been put was discovered on the river side of the mine, and from it a large crystal of smoky quartz was taken that weighed over six hundred pounds. It was forty-three inches high and twenty-eight inches broad and fifteen inches thick. This is now in the University of Texas collection at Austin, Texas.

Very fair amethysts were found in the west end of the hill, in cavities in the feldspar. Masses of biotite, four feet across,

were met with and always indicated the presence near-by of the rare-earth minerals. Some of the fluorite contained small thin veins of a very dark mineral, which was deep indigo-purple by transmitted light, and this may, perhaps, betoken the occurrence of a basic fluoride of the yttrium or cerium earths at this mine and in the region generally.

In a period of four months there was taken out of the hill enough of the yttrium ores to suffice for the Company's needs for the balance of the year, and the mine was therefore closed for the season.

In the following winter (1903-4) the work was again resumed at Barringer-Hill, and about a dozen workmen were kept constantly employed for a period of six months. The scheme of development laid down by the writer in 1902, was carried forward with much energy. Considerable "dead-work" was done in the line of removing "topping" and bringing up the "fall" from the river-side of the hill. New cuts were opened, and the whole top of the hill was blasted away. All the work done at the mine thus far has been of the character of open quarry work, with hand-drilling and the use of powder and dynamite. The mine has been proved to have a deep-seated origin and is only one of a series of so-called "blow-outs" in a region that is entirely granitic. Deep work at this locality may be expected to bring to light new combinations of the rare earths and of uranium and of thorium, as well as great quantities of the species for which the hill is already famous. All the old species will probably be found in a purer state and perhaps in their normal condition as when first crystallized. This last mentioned condition is what we are eagerly seeking for in order to clear up the formulae of many of the species.

During last winter's work all the old minerals, excepting rowlandite, were again found and more than one thousand pounds of very pure gadolinite. The seventy-three pound group of crystals (of gadolinite), found in March, 1903, was the greatest "find" of record in this mineral; but just one year later, a mass of roughly crystallized gadolinite was found, partly imbedded in the bed-rock at the northeast corner of the hill, that measured thirty-six inches long, eleven inches thick at the widest part, and weighed a little over two hundred pounds. It was apparently free from alteration, had specific gravity of 4.28 (taken on a very pure fragment), had a bright green chatoyancy at certain angles, and was like glass in its broad obsidian-like conchoidal fracture.

Upwards of a pound of very pure nivenite and not exceeding an ounce of mackintoshite, were picked out of the many boxes of mixed cyrtolite, fergusonite and thoro-gummite.

Only the density of nivenite saved it from being thrown away as magnetite (very abundant at this mine), and but for its associations it would be always neglected except by the expert mineralogist. Equally so with the mackintoshite, its resemblance to the dark cyrtolite and intimate association with it, prevents it from being recognized by the miner or layman. Some day this mine promises to be worked for the two last-named minerals alone and as the main object of mining there, and in the deeper working they should be found abundantly and in a higher state of purity.

Tengerite (?)—About ten grams of a white mineral, occurring in semi-globular and flat radiated concretions in the cracks and fissures of the gadolinite, were finally obtained after much labor and search. This quantity was the result of detaching the mineral, bit by bit, from over 300 kilos. of fresh gadolinite. Since the composition of tengerite (to which species this substance is tentatively referred) is unknown, I submitted the rare mineral to Dr. W. F. Hillebrand of the U. S. Geol. Survey for analysis; his report is given in full below. The surprising feature is the presence of glucina (BeO) in the form of carbonate, which is new to science, and this may perhaps indicate a new glucinum mineral mechanically mixed with a basic hydrous carbonate of the rare earths of the yttrium group.

Dr. Hillebrand's Report and Analysis.

"The purest material that could be picked out, from that at my disposal, showed some brown admixture with the white. The following results were obtained from .3640 gram of this selected material, after deducting .0262 gram of residue, left after long treatment of the ignited powder with cold and quite dilute nitric acid.

Y_2O_3 group	40.8	per cent	Mol. wt.	226
Ce_2O_3 group	7.0	"	" "	335
Fe_2O_3	4.0	"		
BeO (GlO)	9.7	"		
CO_2	19.6	"		
H_2O above 105°	14.1	"		
H_2O below 105°	3.2	"		
SiO_2	.4	"		
MgO , Alk., loss	1.2	"		
	100.0	"		

All determinations were made on the one portion, the CO_2 and H_2O being directly and simultaneously ascertained by ignition in a tube and collection of the escaping gases. The loss in weight

of the ignited powder agreed with the sum of the CO_2 and H_2O found. Approximate molecular weight determinations of the earths, separated into two portions by potassium sulphate, gave 335 for the cerium group and 226 for the yttrium group, the last being the molecular weight of yttria itself. It is certain that some, if not all, of the ferric oxide reported is foreign to the carbonate, but how much it is impossible to say. The calculated ratios lead to nothing definite, except that the white mineral appears to be a hydrous basic carbonate, but whether a double carbonate of the rare earth metals and glucina, or a mixture, there are no present means of deciding."

Radio-activity.—All the minerals of Barringer-Hill have been experimented with to ascertain the extent of this form of energy present. As early as September, 1902, the writer was at work upon it and had then made successful radiographs from specimens mined at this locality as far back as 1889. In the order of their activity, as shown by their own radiographs, I here mention the species in which the phenomena were observed.

Nivenite (which is a very soluble variety of uraninite) exhibited the most pronounced radio-activity, and beautiful radiographs were made by placing the mineral outside of a photograph plate-holder. Better ones were procured by placing the mineral in direct contact with the sensitive plate—"Cramer's X-ray." Twelve hours exposure, in the dark, developed very good interference figures; but with forty-eight hours, and up to five days exposure, the outlines became as sharp almost as are shown in photographs by sunlight.

Mackintoshite (which is the parent mineral of thoro-gummite) was next in the amount of radio-activity exhibited. It showed about half the intensity of nivenite when compared with equal exposures of the two minerals, side by side, on the same plate.

Positive evidence of the occurrence, within mackintoshite, of little crystals having even a *higher radio-activity* than that shown by the nivenite, was proven by developing the plates used with direct contact. Little bright spots appeared in the field where the less energetic mackintoshite had touched it, and a dull gray border (made by the thoro-gummite coating) united to make a radiograph having *three* degrees of intensity from one mineral specimen. With a strong lens these bright spots, possibly due to a new species, could be identified upon the flattened surface and they were noticed to be very unlike the surrounding mackintoshite. They resembled galena in color and in metallic luster and were quite evenly distributed over the several flat sections examined. Mackintoshite has given evidence, in thin sections, of being translucent, and of a very dull green color by transmitted light, but as the purest

material yet analyzed showed (vide Hillebrand's analysis) 4.31 H₂O present, it is possible that these little bright spots are only the normally pure anhydrous mineral. It is tenable also that these little inclusions, with their high radio-activity, are but a normally pure form of nivenite in which only UO₃ is present. Since mackintoshite can be rationally interpreted as being a mixture of three parts of thorite with one of uraninite (nivenite), the assumption that a new mineral has been discovered may not stand. The question is certainly one of unusual interest at this time and merits further investigation.

Thoro-gummite.—Contact radiographs of this mineral, made from a flattened surface after forty-eight hours exposure, *in the dark*, had much the appearance of ordinary sunlight photographs. All the minute details of structure and varying degrees of radio-activity were beautifully portrayed. It was surprising to note how perfect a picture this mineral could make of itself without any outside aid other than a photographic plate and a long exposure in the dark.

Masses up to a pound weight were found, and this proves that mackintoshite will not be as rare as it is now, when the mine is worked down to lower levels; for thoro-gummite is only an alteration product of mackintoshite, it having assumed one more molecule of water and changed its UO₃ to UO₂, and its color from an apparent jet-black mineral, of specific gravity 5.50, to a dull yellow-brown mineral having specific gravity 4.54+. Long square prisms, like those of zircon, with simple terminal pyramidal planes, were observed.

Yttrialite.—This species gave better radiographs from its altered red crust and its yellow ochreous variety than from the pure dark gray-green anhydrous mineral. All of its radio-activity must emanate from the ten to twelve per cent of thorium present. Hillebrand's last analysis has shown that its composition can best be interpreted by assuming that it is a mixture of an yttrium silicate with the thorite molecule (both anhydrous). Slabs of this mineral eight inches long and six inches broad were broken from some of the larger masses, thus affording fine opportunity for large experimentation in testing it radio-graphically.

Fergusonite.—The mono-hydrated variety made the best radiographs, but all the varieties (of which there are four at the locality) showed more or less action upon the sensitive film.

A new association was discovered in this species. Symmetrically compounded crystals of nivenite with fergusonite were found in the south walling of the hill. Long square prisms of nivenite with flat terminations, had in their centers an equally long but tapering pyramidal crystal of fergusonite, in parallel position. Some of these were one inch long and one-quarter

inch thick. The fergusonite was of the purest kind and almost transparent, and somewhat resembled the famous Spanish sphalerite.

Cyrtolite.—Many hundred pounds were found and in great variety of form and color. All kinds of it gave good radiographs after twenty-four hours exposure. Plates of it as large as one's hand, covered on one side with curved crystals, were not rare. It sometimes encrusted large quartz crystals to the depth of one inch, having radiate structure, and thus afforded a new feature for this mineral and one very uncharacteristic of zircon.

4



Radial Lines from the Ore Masses.—As early as December of 1902, my attention was attracted to the strange occurrence of unusually long radial lines projecting in many directions from the bodies of ore richest in thorium, uranium and zirconium. I then named these occurrences "stars" and eagerly sought for them, as positive "pointers" to ore. At last I was obliged to give these "stars" more than passing attention and here state the reason: While removing, piece by piece, a seventy-pound mass of mixed zirconium-yttrium-uranium and thorium ore, which was a nucleus to one of the best marked of these "stars" (see fig. 4) from its quartz matrix, my hands and face would begin to burn as if from the effect of strong

sunlight, and after two or three days of this kind of mining a redness of skin and a burning sensation would be followed by actual soreness of the parts of my hands and face exposed to the direct emanations from the minerals. My assistant (Mr. J. Edward Turner) complained of it also, and asked me "if these minerals could be poisonous?" As no arsenic was present, the soreness which we both experienced might possibly have been caused by free fluorine, but not by any soluble constituent of the mineral, since salts, such as would be dissolved by the moist skin, had long ago been dissolved, leached out and redeposited in the "chimney" of the mine. It was some time after this that the thought came to me that this action might be the work of a radio-active element and it is offered now more as a suggestion than as a proven fact. I incline strongly to the idea, however, of my having actually experienced the proof of the presence of a very high degree of radio-activity, of a peculiar if not unique kind, at this mine, and that the symptoms above described go a long way towards proving it. Of the true nature of this activity I will not at this time offer any conjectures, but will defer a discussion of it to a paper which is under preparation relating to this very interesting region.

Many photographic records were taken of these "stars," and one of them is shown in fig. 4; they are sometimes eight or ten feet across. Although these radial lines are not new to science, having often been noted elsewhere in connection with allanite, monazite and other rare species, it is not likely that they have been before observed on so large a scale. The cause of this phenomenon has not been determined, so far as I am informed, but it is not without interest that these radial lines are noted only with certain minerals containing rare elements and are most conspicuous with the radio-active species.

ART. XLVI.—*A New Allotrope of Carbon and its Heat of Combustion*; by W. G. MIXER.

[Contributions from the Sheffield Laboratory of Yale University.]

THE investigation of the carbon which separates when acetylene under pressure is exploded forms a part of the study of the thermal constants of the gas. The heat of formation of acetylene according to Thomsen is 47,700 calories; Berthelot's figures are 51,400 calories, and the writer by a direct determination obtained 53,300 calories for the heat of dissociation.* As these results vary so much it appeared desirable to investigate the thermal constants of the constituents of acetylene. The work on hydrogen has been published.† The writer concluded from the study of acetylene that the carbon from it would give a different heat of combustion from that of other forms of carbon. The results obtained confirm this view and indicate that acetylene carbon is a distinct allotropic form. The thermal effect of burning 12 grams of different kinds of carbon found by Favre and Silbermann, Berthelot, and the writer is as follows:

Wood charcoal.	Sugar charcoal.	Gas retort carbon.	Graphite.	Diamond.	
96,960°	96,500°	96,568°	93,559°	93,240°	Favre & Silbermann
97,650°			94,810°	94,310°	Berthelot
	96,700°		94,000°		M.
Acetylene carbon.....					94,728°

The figures show that the carbon from acetylene is very different from the amorphous varieties of the charcoal type, and that its heat of combustion is nearly the same as that of graphite. Moissan has shown that it is not graphite, and does not contain graphite, as it does not yield graphitic acid on treatment with a mixture of potassium chlorate and fuming nitric acid, and my own test gave the same conclusive result.

The acetylene carbon as it comes from the bomb is a greyish black, lusterless and very bulky, porous mass. When compressed it has a brilliant black luster, but not the metallic appearance of graphite. It is a good conductor of heat and electricity. While one gram condenses one milligram of dry air on its surface and in the pores, it does not exert catalytic action on the gases of decay in presence of air, such as we are familiar with in case of charcoal. When a mixture of acetylene carbon and sulphuric acid is boiled no odor of sulphur dioxide is perceptible, but the escaping vapors turn a blue

* This Journal, xii, 347.

† This Journal, xvi, 214.

iodide of starch paper white. Dense sugar charcoal decomposes the hot acid readily. Acetylene carbon absorbs only about, $1/10$ of 1 per cent of its weight of moisture from the air, differing in this respect from charcoal. The determination of density was made as follows: The carbon of the second series of experiments was placed in absolute alcohol, which was then boiled to expel air; ethylene bromide was next added and the boiling repeated. By successive additions of alcohol and bromide a liquid was obtained in which the carbon remained suspended over night. Professor Penfield kindly determined on a Westphal balance the density of this liquid and found it to be 1.919 at common temperature.

First Series of Experiments.

The bomb used for this part of the work was the one described in this Journal, xii, 347, but with the addition of a long narrow neck. Two determinations of the water equivalent of the calorimeter at 20° gave 285 and 281.2 grams and the equivalent calculated from the specific heats of the metals was 284.7 grams. Since the fittings of the calorimeter varied somewhat in the different experiments, the figures for the water equivalent vary slightly. The carbon in a loose bulky mass in the bottom of the bomb was ignited by the glowing magnetic oxide which dropped into it when the iron wire attached to the platinum electrodes was ignited by an electric current. The combustion was explosive in character and complete, and gave a temperature that fused the ends of the thick platinum wires. The thermometer would rise perceptibly in three seconds after passing the electric current. The oxygen used was made from potassium chlorate and collected in a glass gas holder over a dilute solution of potassium hydroxide. In order to have the bomb fairly free from nitrogen it was repeatedly exhausted and filled with oxygen and then the gas was pumped in until the pressure was between 10 and 15 atmospheres. The weight of the oxygen was found by weighing the bomb before and after filling it with the gas.

In the first three experiments the silver plating protected the steel from oxidation, and the silver dissolved by the nitric acid formed was not determined. For the remaining tests the bomb was lined with a tight fitting shell of silver 1^{mm} in thickness, and the silver dissolved was precipitated and weighed as chloride. The heat of burning 1 mg. of iron was considered to be 1.6 calory.

The air condensed on the surface of the carbon in the loose form in which it was weighed for the various experiments was found as follows:

A cylindrical glass vessel with a long neck and stopcock and having a capacity of 67^{cc} was filled with 3 grams of acetylene carbon. It was exhausted and heated for an hour to about 400° and then allowed to cool and the stopcock closed, the mercury pump being in action all the time. Next it was counterpoised by a similar vessel and the needed weights, and finally dry air was admitted and the increase in weight observed. The data required are the weight and density of the carbon, the capacity of the vessel, the weight of the air admitted, the temperature and barometric pressure. The results of three determinations were 3.2, 3.4, and 3.1 milligrams of air condensed by 3 grams of the carbon. The apparatus was crude and the result is to be regarded merely as proving that but little air is condensed by the carbon.

The carbon for the first series of tests was from the sample obtained three years ago in the determination of the heat of dissociation of acetylene.* It contained a little incombustible matter or ash derived from the bomb and the impurities of the gas from which it was made. The composition of it was found as follows: The carbon was compressed in a large platinum tray open at one end and nearly closed on top and the tray and contents were placed in a long narrow platinum crucible with a close-fitting cover and heated to redness. After cooling over sulphuric acid the whole was weighed, then heated again, allowed to cool as before and then the weight was quickly taken. With these precautions the error due to moisture is negligible. The observed weight was corrected for ash, absorbed air and reduced to weight in vacuum. The combustion was made with oxygen and oxide of copper. The water was absorbed in a U-tube filled with beads drenched with sulphuric acid and the carbon dioxide by a solution of potassium hydroxide in a helical tube, the unabsorbed gas passing through a U-tube filled with solid potassium hydroxide and then through another tube containing beads drenched with sulphuric acid. To the last tube there was an attachment to keep out moisture. Each piece of absorption apparatus was counterpoised on the balance by a similar one to eliminate the effects of atmospheric changes. For each gram of carbon dioxide 0.5 of a milligram was added for reduction to weight in vacuum. This was the correction calculated for the solution of potassium hydroxide used which had a density of 1.38; it was also found by experiment to be the same. The calculations are based on the atomic weights 12 and 16 of carbon and oxygen respectively. The following are the results:

* Loc. cit.

	I.	II.	Mean.
Acetylene carbon taken...	1·1485	1·3838 gram	
Carbon	99·93	99·96	99·95 per cent
Hydrogen.....	0·04	0·03	0·03 “

The weight of the substance, corrected as already described, multiplied by 0·9995 was taken to be the amount of carbon burned in the calorimeter. The specific heat of both oxygen and carbon dioxide at constant volume is very nearly 0·15. Hence the product of this number by the total weight of the carbon and oxygen is included in the water equivalent of the calorimetric system. The observed weight of the water in the calorimeter was reduced to weight in vacuum. The temperature observed the instant before an explosion was taken as the initial temperature and it was assumed that the gain and loss of heat were equal during the first minute after an explosion, and correction was made for the loss during the four minutes following. Thermometer No. 172863, described in the paper on “The Heat of Combustion of Hydrogen,”* was used in this first series of experiments.

Experiment 1.—Carbon 1·3740, hydrogen 0·0004, iron 0·070, oxygen 10·2 grams.

Water.....	2190·	grams
Water equivalent of calorimeter.....	258·6	“
“ “ carbon dioxide		
and oxygen	1·7	“
	<hr/>	
	2450·3	“

Minutes.	Temperature.	Temperature interval.
0	18·700	
1	18·700	23·124—18·7 + 0·04 = 4·464°
2	22·5	
3	23·115	Heat observed, 2450·3 × 4·464 = 10938°
4	23·139	“ of oxidation of iron — 112°
5	23·133	“ “ “ hydrogen — 14°
6	23·124	<hr/>
7	23·113	10812°
8	23·102	
9	23·092	For 1 gram of carbon 7869°

The water with which the bomb was washed after the experiment was free from silver.

Experiment 2.—Carbon 1·0318, hydrogen 0·0003, iron 0·030, oxygen 10·5, water and water equivalent 2543·4 grams.

* This Journal, xvi, 214.

Minutes.	Temperature.	Temperature interval.
0	18·426	
1	18·430	$21·669 - 18·442 + 0·009 = 3·236^{\circ}$
2	18·434	
3	18·437	Heat observed, $2543·4 \times 3·236 = 8230·6^{\circ}$
4	18·442	“ of oxidation of iron -48°
5	21·4	“ “ “ hydrogen $-10·2^{\circ}$
6	21·672	
7	21·672	
8	21·672	For 1 gram of carbon $8172·4^{\circ}$
9	21·669	
10	21·666	The slight amount of silver dissolved
11	21·664	was not determined.
12	21·661	
13	21·659	
14	21·657	

Experiment 3.—Carbon 1·1136, hydrogen 0·0003, iron 0·030, oxygen 10·5, water and water equivalent 2599·6 grams.

Minutes.	Temperature.	Temperature interval.
0	18·843	
1	18·845	$22·230 - 18·851 + 0·02 = 3·399^{\circ}$
2	18·847	
3	18·849	Heat observed, $2599·6 \times 3·399 = 8836·1^{\circ}$
4	18·851	“ of oxidation of iron -48°
5	21·95	“ “ “ hydrogen -11°
6	22·231	
7	22·238	
8	22·235	For 1 gram of carbon $8777·1^{\circ}$
9	22·230	
10	22·226	
11	22·221	
12	22·216	

In the next three experiments a larger german silver calorimeter can was used and the bomb was lined with pure silver as already described.

Experiment 4.—Carbon 1·2688, hydrogen 0·0004, iron 0·050, oxygen 10, water and water equivalent 3434·8 grams.

Minutes.	Temperature.	Temperature interval.
0	18·381	$21·315 - 18·381 + 0·018 = 2·952^{\circ}$
1	18·381	
2	18·381	Heat observed, $3434·8 \times 2·952 = 10139·6^{\circ}$
6	21·309	“ of oxidation of iron -80°
7	21·315	“ “ “ hydrogen $-13·6^{\circ}$
8	21·312	“ of formation of silver nitrate $-18·4^{\circ}$
9	21·307	
10	21·302	
11	21·297	For 1 gram of carbon $10027·6^{\circ}$
12	21·292	

According to Thomsen* the thermal effect of the formation from its elements of $\text{Ag}_2\text{N}_2\text{O}_4$ and solution in water is 46,600 calories. From which we find that 1 mlg. of silver dissolved corresponds to 0.216° . The solution from the interior of the bomb after an explosion in no instance reacted acid to ordinary litmus paper, showing that the nitric acid was mostly taken up by the silver. In experiment 4, 85.4 mlgs. of silver were found in rinsings, showing 18.4° were due to the oxidation of nitrogen and solution of silver.

Experiment 5.—Carbon 1.3054, hydrogen 0.0004, iron 0.0385, silver dissolved 0.0726, oxygen 10.2, water and water equivalent 3302.2 grams.

Minutes.	Temperature.	Temperature interval.
0	18.958	
1	18.958	$22.083 - 18.958 + 0.021 = 3.146^\circ$
2	18.958	
3	21.8	Heat observed, $3302.2 \times 3.146 = 10388.7^\circ$
4	22.079	“ of oxidation of iron -61.6°
5	22.092	“ “ “ hydrogen -13.6°
6	22.088	“ formation of silver nitrate -15.7°
7	22.083	
8	23.077	10297.8 ^c
9	22.073	For 1 gram of carbon 7888.8 ^c
10	22.067	
11	22.062	
12	22.055	
13	22.051	

Experiment 6.—Carbon 1.3277, hydrogen 0.0004, iron 0.040, silver dissolved 0.0918, oxygen 9.7, water and water equivalent 3253.9 grams.

Minutes.	Temperature.	Temperature interval.
0	18.894	
1	18.896	$22.135 - 18.9 + 0.014 = 3.249^\circ$
2	18.898	
3	18.900	Heat observed, $3253.9 \times 3.249 = 10572.^\circ$
4	21.9	“ of oxidation of iron $-64.^\circ$
5	22.129	“ “ “ hydrogen -13.6°
6	22.139	“ formation of silver nitrate -19.8°
7	22.137	
8	22.135	10474.6 ^c
9	22.131	For 1 gram of carbon 7889.4 ^c
10	22.127	The gas in the bomb after the calorimetric test was transferred to a gas holder containing a solution of caustic potash and was left several hours to ensure the complete absorption of carbon dioxide. It was then passed into a solution of barium hydroxide and
11	22.124	
12	22.121	
13	22.117	
14	22.114	
15	22.111	
16	22.108	

* Thermo-Chem. Untersuchungen, iii, p. 282.

over glowing copper oxide, and finally through a clear solution of barium hydroxide. The barium solutions remained clear. In the delivery tube in the second there was a faint white ring indicating that the gas contained a trace of carbonic oxide. The same result was obtained in subsequent experiments and is what might be expected in a cooling mixture of oxygen, carbon dioxide and carbonic oxide formed directly from the burning of the carbon and by the dissociation of carbon dioxide by heat. The amount of carbonic oxide remaining in the bomb was, however, too small to be estimated by ordinary methods or to have an appreciable influence on the thermal result.

The mean of the foregoing results is 7892· calories for one gram of carbon. This is considerably less than other investigators found for amorphous carbon and not much higher than obtained for graphite. In order to find if the variation was due to a constant error, sugar charcoal and graphite were burned in the apparatus used for experiments 4, 5, and 6.

Sugar Charcoal.

The charcoal was prepared by charring sugar and heating the coal for several hours in a Perrot furnace: next it was heated for two hours in a current of chlorine, and finally it was kept at a white heat for six hours. The product contained a trace of chlorine and 1/10 of 1 per cent of ash. The carbon and hydrogen were determined with the precautions already described. The following results are for the ash-free coal:

	I.	II.	Mean.
Carbon	99·08	99·04	99·06
Hydrogen	0·13	0·13	0·13
Oxygen ?	----	----	(0·81)
			<hr/> 100·00

The thermal results obtained, less the heat of combustion of the hydrogen content, were 8028, 8023 and 8027, mean 8026 calories for one gram of carbon. Considering that 0·81 per cent of the charcoal is oxygen in combination with hydrogen we have 8057 calories. Neither method of allowing for the hydrogen is to be considered as accurate, and the first correction is excessive.

Graphite.

Compact crystalline graphite associated with calcite was pulverized, digested with hydrochloric acid and washed. Thus purified it contained 0·32 per cent of ash. The analysis of the combustible portion gave

	I.	II.
Carbon	99·90	99·89
Hydrogen	0·01	0·02

The graphite is probably free from hydrogen as the amount given above is within the limits of error. Three calorimetric tests, using for each about 1.6 gram, gave 7836, 7848 and 7810, mean 7831 calories for the heat of combustion of one gram of graphite.

Second Series of Experiments.

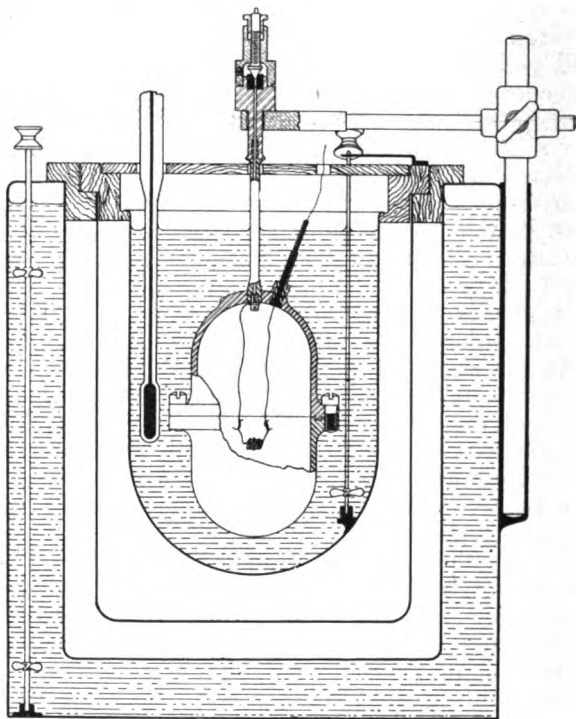
The carbon for this series was prepared as follows: Acetylene gas from carbide was passed through a long tube containing solid potassium hydroxide then pumped into the bomb through another tube two meters in length filled with fragments of potassium hydroxide. The one to two per cent impurity in the gas was chiefly nitrogen and oxygen. A little phosphureted hydrogen was also present. The gas at an initial pressure of about 10 atmospheres was fired by an electric spark between the neck of the bomb and the valve. The thermal effects for one gram of acetylene in four tests were 2063, 2080, 2075 and 2070, mean 2072 calories. This is 32 calories higher than the result obtained in the work* which yielded the carbon used in the first series of experiments. The hydrogen gas remaining after the explosion was free from acetylene but contained a little hydrocyanic acid.

The carbon was tested for hydrogen as follows: Two blank trials of the combustion apparatus were made using about 4 liters of oxygen and air in each. The sulphuric-acid absorption tube before the combustion tube gained 1.2 and 1.3 mlgs., and the one at the other end 2.1 and 0.6 mlgs., respectively, in the two tests. Then 2.11 grams of the carbon which had been heated to redness and cooled in a desiccator were placed in the combustion tube, and heated for a time in a current of dry air to drive off any water present. Next the absorption tubes were connected and the combustion was made in the usual way. The anterior tube gained 1.3 mlg. and the one through which the products passed gained 4.2 mlgs. The cause of the increase of the anterior tube was not evident. The oxygen and air used were dried by caustic potash and calcium chloride and then passed through a long U-tube filled with beads drenched with the same sulphuric used in the weighed tubes. It is evident that the gain of 4.2 mlgs., equivalent to 0.02 per cent of hydrogen, may be due to something other than water formed in the combustion of the substance, and we may assume that the carbon was either free from hydrogen or contained too little to be considered in the calorimetric results.

The carbon was repeatedly digested with a mixture of nitric acid, density 1.57, and potassium chlorate and was finally completely oxidized, leaving, however, a few minute transparent particles. When it was oxidized in other ways similar particles were found.

* Loc. cit.

The calorimeter used in this second series of experiments is shown in the figure. The bomb was silver plated and lined with pure silver a millimeter in thickness. The water equivalent of the calorimeter is less than one-tenth of the water it contained. Thermometer No. 1, described in the paper on hydrogen (*loc. cit.*) was used.



Experiment 1.—

Observed weight of carbon	1.5057 gram
Air condensed on "	— 0.0017 "
Reduction for weight in vacuum.. +	0.0008 "
Corrected weight	1.5048 "
Observed weight of water	3255.5 grams
Reduction for weight in vacuum	3.2 "
Water equivalent of oxygen and carbon dioxide	1.7 "
Water equivalent of calorimeter	286.6 "
Water and water equivalent	3547 "
Oxygen	9.7 "
Iron wire to ignite the carbon	44 milligrams
Silver dissolved by HNO ₃ formed	38 "

Minutes.	Temperature.	Temperature interval.
0	18·421	
1	18·426	21·811—18·436 + 0·007 = 3·382°
2	18·431	
3	18·436	
4	21·8	
5	21·810	Heat observed, $3547 \times 3·382 = 11996^\circ$
6	21·816	“ of oxidation of iron — 70·4°
7	21·813	“ of formation of silver nitrate — 8·2°
8	21·811	
9	21·809	Heat of combustion of 1·5048
10	21·807	gram of carbon 11917·4°
11	21·805	Heat of combustion of 1 gram
12	21·803	of carbon 7919·6°
13	21·802	
14	21·801	
15	21·399	

Experiment 2.—Carbon 1·4304, iron 0·040, silver dissolved 0·048, oxygen 10·5, water and water equivalent, 3637·6 grams.

Minutes.	Temperature.	Temperature interval.
0	19·263	
1	19·268	22·394—18·272 + 0·003 = 3·125°
3	19·272	
4	22·	Heat observed, $3637·6 \times 3·125 = 11367·5^\circ$
5	22·39	“ of oxidation of iron — 64· °
6	22·395	“ of formation of silver nitrate — 10·4°
7	22·394	
8	22·392	11293·1°
9	22·392	For 1 gram of carbon 7895· °
10	22·392	
11	22·391	
12	22·390	
13	22·389	
14	22·388	

Experiment 3.—Carbon 1·5354, iron 0·031, silver dissolved 0·064, oxygen 10·6, water and water equivalent 3618 grams.

Minutes.	Temperature.	Temperature interval.
0	19·104	
1	19·108	22·466—19·112 + 0·010 = 3·364°
2	19·112	
3	22·25	Heat observed, $3618 \times 3·364 = 12171^\circ$
4	22·472	“ of oxidation of iron — 49·6°
5	22·472	“ of formation of silver nitrate — 13·6°
6	22·470	
7	22·466	12107·8°
8	22·463	For 1 gram of carbon 7885·7°
9	22·461	
10	22·458	
11	22·456	
12	22·454	
13	22·451	
14	22·449	

444 *W. G. Mixer—Carbon and its Heat of Combustion.*

Experiment 4.—Carbon 1·361, iron 0·032, silver dissolved 0·013, oxygen 10·5, water and water equivalent 3511·5 grams.

Minutes.	Temperature.	Temperature interval.
0	18·777	
1	18·780	$21·848 - 18·786 + 0·008 = 3·070^{\circ}$
2	18·783	
3	18·786	Heat observed, $3511·5 \times 3·07 = 10780·3^{\circ}$
4	21·8	“ of oxidation of iron $- 51·2^{\circ}$
5	21·853	“ of formation of silver nitrate $- 2·7^{\circ}$
6	21·853	
7	21·851	<hr/> 10726·4°
8	21·848	For 1 gram of carbon 7881·3°
9	21·845	
10	21·843	
11	21·841	
12	21·839	
13	21·838	

Summary of Results.

Experiment No.	First series.	Second series.
1	7869	7919·6
2	7919·5	7895
3	7881·7	7885·7
4	7903·4	7881·3
5	7888·8	
6	7889·4	
Average	7892·	7895·4

The mean of the results of the two series of experiments is 7894 calories for the heat of combustion of one gram of acetylene carbon at constant pressure and volume and at about 20° and in terms of the water calorie at this temperature, and for 12 grams it is 94,728 calories.

ART. XLVII.—*Reflection of Light by Colored Papers*; by
HOWARD D. MINCHIN.

ALTHOUGH the subject of reflection of light by various surfaces has received much attention, the question of the reflecting power of colored papers and of wall papers in particular seems to have attracted little notice. The importance of the subject from an economic as well as from an artistic standpoint would seem to justify the attempt to settle certain features in the question even though the treatment be little more than qualitative.

The investigation is complicated at the outset by our inability to specify definitely the exact sample of paper under examination as well as by our inability to reproduce such sample for purposes of subsequent comparison and measurement. Nevertheless it has been thought worth while to submit the result of a series of measurements upon the reflective powers of a set of ordinary commercial papers.

Under the head of metallic reflection the classic investigation of Hagen and Rubens,* Langley,† Nichols,‡ Jamin,§ Quincke,|| and Drude,¶ are of the first importance. Wright,** studied diffuse reflection of light on matt surfaces, while the reflective powers of mercury and glass were investigated by Walbott,†† and Walker,‡‡ respectively. Investigations touching the reflection of light by colored papers are, so far as known to the author, confined to the writings of Abney,§ Abney and Festing,|| and of Kononowitsch,¶¶ but in none of these can be found any mention of the subject under consideration.

Apparatus and Method.

The measurements of the investigation here discussed were made by means of a Brace spectrophotometer consisting of two collimators T and T', a telescope A, and a Brace prism P (fig. 1). The sources of light were two 220 volt 16 candle power incandescent lamps. One was permanently fixed at

* Hagen and Rubens, *Ann. d. Physik.*, i, 352, 1900.

† S. P. Langley, *Phil. Mag.*, xxvii, 10, 1889.

‡ E. L. Nichols, *Wied. Ann.*, ix, 401, 1897.

§ J. Jamin, *Ann. Chim. Phys.* (3), xxii, 311, 1848.

|| G. Quincke, *Pogg. Ann. Jubelb'd.*, 336, 1874.

¶ P. Drude, *Wied. Ann.*, xxxix, 481, 1890.

** H. R. Wright, *Phil. Mag.* (5), xlix, 199, 1900.

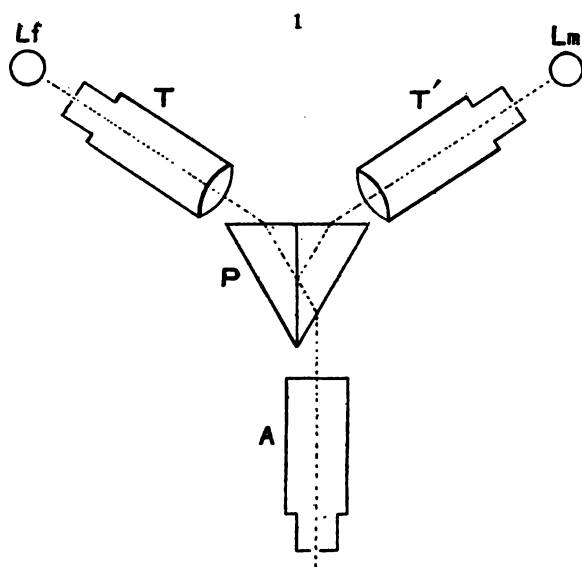
†† H. Walbott, *Wied. Ann.*, lxviii, 471, 1899.

‡‡ B. Walker, *Wied. Ann.*, lii, 762, 1894.

§§ Abney, *Roy. Soc. Proc.*, lxvii, 118, 1900.

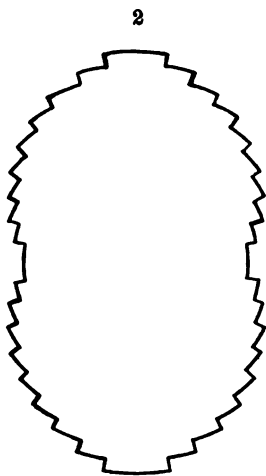
|| Abney and Festing, *Phil. Trans.*, clxxii, 887, 1882.

¶¶ Kononowitsch, *Wied. Ann.*, lxvi, 317, 1897.



collimator T, in which the slit was adjusted to some desired width. The second lamp was used at collimator T', first directly in front of the slit and afterwards at one side, the light from it being reflected into T' by the reflecting surface.

Care was taken so to shield the lamps that no light reached the prism P, except that coming through the slits. To obtain a more uniform field ground glass plates were placed directly in front of the slits.



A revolving disk (fig. 2) similar to that described by Brace* was placed in front of T, by means of which the intensity of the light admitted to the slit could be varied by tenths, giving 0.1, 0.2, 0.3, etc., of the full intensity. The disk was driven by an electric motor as described by Murphy.†

With the lamps placed directly in front of the two collimators and the slit in collimator T set at a definite width, the slit in T' was calibrated by means of the rotating disk, according

to the method described by Capp,‡ for the five colors:

* Brace, *Astro-Physical Journal*, xi, 6.

† Murphy, " " " vi, 5.

‡ Capp, " " " vii, 25.

red, $\lambda = 0.0006562^{\text{mm}}$
yellow, $\lambda = 0.0005893^{\text{mm}}$
green, $\lambda = 0.0005460^{\text{mm}}$
blue, $\lambda = 0.0004862^{\text{mm}}$
violet, $\lambda = 0.0004357^{\text{mm}}$

The slit in T' was adjusted for a match first with the total light admitted at T , then with 0.5, 0.3, 0.2, and 0.1, the total light.

8

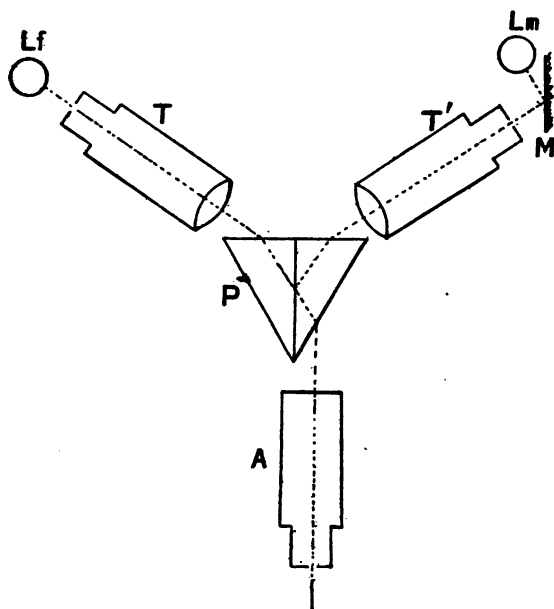


Table I gives the required width of T' in mm. for a match in the different colors when T is 0.2^{mm} in width. All values recorded are the average of eight readings. *Data:*

TABLE I.

Width of T' in mm.

Color.	For intensities of				
	1.0	0.5	0.3	0.2	0.1
Red	0.263	0.146	0.095	0.071	0.041
Yellow	0.293	0.165	0.099	0.079	0.042
Green	0.307	0.171	0.105	0.082	0.046
Blue	0.334	0.183	0.118	0.090	0.055
Violet	0.368	0.189	0.103	0.105	0.048

The lamp at T' was next placed at one side and a mirror fixed at T' to reflect the light into the slit. Fig. 3 shows the arrangement.

The length of the light path was kept constant and the angle of incidence was made 45° . The results are given in Table II.

TABLE II.
Width of T' when mirror is used.
Intensities at T.

Color.	1.0	0.5	0.3	0.1
Red	0.569	0.276	0.190	0.081
Yellow	0.607	0.305	0.198	0.084
Green	0.621	0.332	0.209	0.091
Blue	0.685	0.381	0.238	0.109
Violet	0.810	0.392	0.204	0.094

The colored paper was substituted for the mirror and adjustments of T' made as before. The following tables give the results for the paper used :

(The interrogation point denotes some light, but not sufficient for a match. 0 means no trace of color noticeable.)

Width of T' when T = 0.1mm .

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
	Red	1.287	1.878	2.697	?	..
Deep red	Yellow	?	----	----	--	--
	Green	?	----	----	--	--
	Blue	?	----	----	--	--
	Violet	0	0	0	0	0

Width of T' when T = 0.2mm .

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
	Red	0.460	0.889	--	1.680	2.009
Light red	Yellow	?	----	--	----	----
	Green	*	----	--	----	----
	Blue	2.235	----	--	----	----
	Violet	?	----	--	----	----

Width of T' when T = 0.2mm .

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
	Red	1.903	?	--	--	--
Dark green	Yellow	2.650	?	--	--	--
	Green	1.810	?	--	--	--
	Blue	2.122	?	--	--	--
	Violet	2.418	?	--	--	--

* When T' was narrow a little green was seen, but when T' was widened for a match all trace of green disappeared.

Width of T' when T = 0.1mm.

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
Dull green	Red	1.424	?	--	--	--
	Yellow	1.302	?	--	--	--
	Green	1.056	2.091	?	--	--
	Blue	1.450	2.278	?	--	--
	Violet	?	--	--	--	--

Width of T' when T = 0.1mm.

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
Light green	Red	1.289	2.120	?	--	--
	Yellow	1.176	2.204	?	--	--
	Green	0.683	1.299	2.029	?	--
	Blue	0.782	1.280	1.912	2.129	2.710
	Violet	Just a slight trace				

Width of T' when T = 0.2mm.

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
Dark blue	Red	1.847	?	--	--	--
	Yellow	?	--	--	--	--
	Green	?	--	--	--	--
	Blue	4.667	--	--	--	--
	Violet	?	--	--	--	--

Width of T' when T = 0.1mm.

Paper.	Color reflected.	Intensities at T.				
		0.1	0.2	0.3	0.4	0.5
Light blue	Red	1.213	2.061	?	--	--
	Yellow	1.088	1.980	?	--	--
	Green	0.936	1.684	2.521	?	--
	Blue	0.789	1.505	2.096	?	--
	Violet	1.036	1.111	1.631	2.117	2.886

Discussion of Data.

Table II shows that approximately one half the incident light was reflected by the mirror. Both Table I and Table II show that as the violet end of the spectrum was approached the width of T' had to be increased to procure a match.

Because of the small amount of light reflected by the papers it became necessary to cut down the intensity of the light admitted at T. Each of the tables gives the greatest intensities that could be used and allow the obtaining of a match.

The deep red paper reflected red light only, to a sufficient degree to allow of a match.

The intensity of the light reflected by the light red paper was very low and it was necessary to narrow T to 0.1^{mm}. A match was then obtained for red and blue.

The green papers reflected all colors in considerable amounts. The dark green reflected red and green light about equally, while the light green reflected less of the red and reflected green and blue in about the same amounts, but as the intensity of the light admitted at T was increased more blue than green was reflected.

The dark blue paper reflected red light of an intensity about two and one-half times the intensity of the blue reflected. The other colors were reflected in very small amounts.

With the light blue paper all the colors were reflected when the intensity at T was 0.1 or 0.2, and with intensities at T of 0.4 and 0.5 a match was obtained with violet light only.

A comparison of all the papers used can be made only for an intensity of light admitted at T of 0.1. The following table gives the width of T' in terms of T for a match in the different colors. For example, in the red when light was admitted directly, T' was 0.21 times the width of T for match, when the mirror was used T' was 0.41 times the width of T, etc.

Light from.	T' in terms of T.				
	Colors.				
	Red.	Yellow.	Green.	Blue.	Violet.
Direct	0.21	0.21	0.23	0.28	0.24
Mirror	0.41	0.42	0.46	0.55	0.47
Deep red	6.44	?	?	?	?
Light red	4.60	?	?	22.34	?
Dark green	9.52	13.25	9.05	15.61	12.09
Dull green	14.24	13.02	10.56	14.50	?
Light green	12.89	11.76	6.83	7.82	?
Dark blue	9.24	?	?	23.34	?
Light blue	12.13	10.88	9.36	7.89	10.36

The dark green and the light blue papers are the only papers that reflected all colors sufficiently to obtain a match. The light green and the dull green papers are the next in order, both the latter reflected very little violet light. The light reflected by the dark green and the light blue papers is more nearly white light than that from any of the other papers used.

Less than 0.02 of the incident light was reflected by the best paper used, when all conditions were the best possible.

The observations embodied in this paper were made in the Physical Laboratory of the University of Michigan, at the suggestion of Professor Reed, to whom thanks are due for his interest and assistance during the progress of the investigation.

Physical Laboratory, University of Rochester, January, 1905.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *New Experiments in Preparing Diamonds.*—In his examination of the Canyon Diablo meteorite, MOISSAN noticed that the diamonds found in it occurred in fissures containing sulphide of iron, and it seemed possible that sulphur might have had an influence in the formation of these crystals. He has, therefore, made some new experiments upon the formation of diamonds by crystallization from iron saturated with carbon in the electrical furnace and rapidly cooled with water, and has modified his experiments of several years ago by additions of sulphide of iron, silicide of iron, or phosphide of iron to the fused metal before cooling. The results showed that the production of diamonds was somewhat better in the presence of sulphur than had formerly been the case without this addition, and silicon appeared also to exert a favorable influence, but in this case more difficulty was encountered in the separation of the diamonds from the ingot, on account of the presence of carbide of silicon. No diamonds were obtained in two experiments where phosphide of iron was added. Some of the diamonds produced in the presence of sulphur were large enough to be separated with the naked eye by means of a steel point, while the largest of those made in the presence of silicon had a length of $.75^{\text{mm}}$. Their size is of the same order as that of those from the meteorite, and they are practically microscopic objects. Moissan has confirmed his previous conclusion that the artificial substance is actually diamond, and he finds that, like the natural substance, it often shows weak double refraction. He regards the diamond as a form of carbon which has been liquefied under high pressure, since he has shown previously that at ordinary pressure all forms of carbon vaporize without becoming liquid, and all produce graphite.—*Comptes Rendus*, cxi, 277.

H. L. W.

2. *Atomic Weights of Sodium and Chlorine.*—T. W. RICHARDS and R. C. WELLS have made a very elaborate investigation in revising these important atomic weights. As is usual with the work of Richards, the greatest precautions have been taken in purifying materials, detecting sources of error and avoiding or making accurate allowances for them, and in the use of varied methods and materials. The description of the work inspires the utmost confidence in it, as well as admiration for the skill and patience displayed in carrying it out. As a result of their research it appears that the work of Stas on the atomic weights in question was slightly erroneous. From a study of the ratios $\text{AgCl} : \text{NaCl}$, $\text{Ag} : \text{NaCl}$, and $\text{Ag} : \text{AgCl}$, they find that when the atomic weight of silver is taken as 107.930, sodium is 23.008, and chlorine is 35.473, whereas the previously accepted numbers are 23.05 and 35.45. Many other atomic weights are affected, in

their second decimal places, by these changes, and a recalculation of the atomic weights will be necessary soon. Richards suggests, however, that this systematic recalculation be delayed until a few other new data should have been obtained—in particular, new analyses of potassium chloride, silver chlorate, the bromides, sulphides and sulphates, and similar important compounds. Some of these are already being made, and others will be undertaken at once by Professor Richards.—*Carnegie Institution of Washington*. Publication No. 28. H. L. W.

3. *The Origin of Radium*.—A continuation of the investigations of Dr. B. B. BOLTWOOD upon the relative quantities of uranium and radium in various minerals, an account of which appeared in the preceding volume of this Journal, shows that these quantities are proportional to one another, within the limits of experimental errors, even in minerals containing much thorium and very small amounts of uranium. The more recent experiments were the examination of twenty-two specimens of minerals where the accurately determined percentages of uranium vary from 74 to 0.3 per cent, and in this series allowance is made for the emanation lost at ordinary temperatures by the various samples. The author says that the inevitable and only possible conclusion from the results is that uranium is the parent of radium, and that the participation of thorium in the production of radium, which has been suggested by some, is entirely excluded. He also mentions experiments made to determine whether radium is formed directly from uranium. These showed no evidence of this change after a period of seven months and confirm the results of similar experiments by Soddy, so that it is probable, as suggested by Rutherford, that one or more intermediate changes exist between the uranium atom and the radium atom. Attention is called to the persistent appearance of lead as a constituent of uranium-radium minerals as an indication that this metal may be one of the final products of the disintegration of uranium.—*Phil. Mag.* (6), ix, 599. H. L. W.

4. *Marceli Nencki, Opera Omnia—Gesammelte Arbeiten von Prof. M. NENCKI*—Erster Band, 1869–1885; Zweiter Band, 1886–1901. Large 8vo, pp. xliii + 840, and xiii + 893. Braunschweig, 1905. (Friedrich Vieweg und Sohn.)—These two sumptuous volumes, edited by N. Sieber and J. Zaleski, contain a fine portrait of Nencki as a frontispiece, a sketch of his life, a complete collection of his scientific writings, as well as numerous articles by pupils working under his direction. The work is an important and useful one, because Nencki's publications are scattered through many different journals, and because of the scientific value of his researches. Nencki's work covers a wide field, and the articles have been systematically indexed by the editors. There are many important investigations in pure chemistry—it is said that he took pride in having made over one thousand elementary analyses—but it is well known that his most important work was in the lines of physiological and medical chemistry, and

the book will be particularly useful to those interested in these branches of science.

H. L. W.

5. *Manual of Chemical Analysis as Applied to the Assay of Fuels, Ores, Metals, Alloys, Salts, and other Mineral Products*; by EUGÈNE PROST; translated by J. CRUICKSHANK SMITH. 8vo, pp. 300. London, Maclaren & Sons; New York, D. Van Nostrand Company, 1904.—The object and scope of this work are set forth in the title. It should serve as a useful book of reference for analytical chemists engaged in technical work, for many of the methods of analysis are well selected and carefully described. A good feature of the book is the introduction of typical analyses of many commercial products, which give the chemist an idea of the ingredients to be looked for as well as the extent to which they are liable to occur. The book may be criticized on account of failing to include certain useful and reliable methods. For instance, Drown's method for the determination of silicon in pig iron is not given, while tared paper filters are recommended for weighing precipitates in cases where the Gooch crucible would give far better service, and other antiquated features from an American point of view are to be noticed. Not all of the methods are described in such a way that they would give a satisfactory degree of accuracy when implicitly followed, and in some cases the directions are decidedly lacking in completeness, or the methods are faulty in principle. The book is, therefore, not a perfect one, although it contains much that is useful. It seems unfortunate that the translator should have employed incorrect chemical nomenclature in some cases; for instance, chloride of soda for sodium chloride.

H. L. W.

6. *Radiation Pressure*.—Professor POYNTING discusses simple methods of showing the pressure of light, and applies his theory of the stream of momentum. Theory and experiment seem to indicate that when a source is sending out waves it is pouring out with them forward momentum as well as energy, the momentum being manifested in the reaction, the back pressure against the source, and in the forward pressure when the waves reach an opposing surface. The wave train may be regarded as a stream of momentum traveling through space. Radiation pressure has not succeeded in explaining the repulsion of comet's tails. Professor Poynting suggests the following explanation of Saturn's rings: Let us imagine that a small sun while still radiating much energy on its own account has captured and attached to itself as satellite a cometary cloud of dust. Then, if the cloud consists of particles of different sizes, while all will tend to draw into the primary, the larger particles will draw in more slowly. But if the larger particles are of different sizes among themselves, they will have different periods of revolution, and will gradually form a ring all round the planet on the outside. Meanwhile the finer particles will drift in, and again differences in size will correspond to difference in period and they too will spread all around, forming an inner fringe to the ring. If there are several grades

of dust with gaps in the scale of size, the different grades will form different rings in time.—*Phil. Mag.*, April, 1905. J. T.

7. *Spontaneous Ionization of Air in closed Vessels and its Causes.*—The conductivity of air and other gases is generally attributed to the presence of free ions, and as these free ions are continually recombining there is some agency which is splitting up the combinations. Ionization in which no artificial ionization agent is employed has been called spontaneous ionization. The hypothesis that the ionization is due to a penetrating radiation constantly passing through the atmosphere has been advanced and is largely adopted. ALEXANDER WOOD of Emmanuel College, Cambridge, believes from a careful inspection of indirect evidence that all matter is radio-active and that the disintegration processes going on in radium and the other radio-active elements are going on also, though to a much smaller extent, in all matter.—*Phil. Mag.*, April, 1905. J. T.

8. *Radio-activity and Chemical Change.*—N. R. CAMPBELL finds that there is no evidence that chemical change is accompanied by radio-activity; and that the spontaneous leak increase which has led some investigators to suggest such a connection is due to the heating of the walls of the vessels.—*Phil. Mag.*, April, 1905. J. T.

9. *Helium Tubes as Indicators of Electric Waves.*—Geissler tubes filled with argon, neon and other gases have been used by various investigators of electric waves along wires. ERNST DORN finds that tubes filled with helium, 5.5 mm pressure are very sensitive and do not require a dark room.—*Ann. der Phys.*, No. 4, 1905, pp. 784–788. J. T.

10. *The Specific Heat of Water and the Mechanical Equivalent of Heat.*—The leading article in the *Annalen der Physik*, No. 4, 1905, by C. DIETERICI, is a careful consideration of this subject, and is remarkable for the use the author makes of vessels of amorphous quartz. The method adopted in determining the specific heat of water was to enclose a definite quantity in a quartz cylinder and after raising it to a measured temperature to suddenly immerse it in a Bunsen ice calorimeter. The value $419.25 \times 10^6 \frac{\text{erg.}}{\text{cal.}}$ was obtained for the mechanical equivalent of

heat.—*Ann. der Phys.*, No. 4, 1905, pp. 593–621. J. T.

11. *Photograph of the Solar Corona without a Total Eclipse.*—In the opinion of M. J. JANSSEN, M. A. HANSKY has succeeded in photographing the corona of the uneclipsed sun. The results were obtained at the observatory of Mt. Blanc by the use of the selective absorption of different screens. The direct rays of the sun were shut off by a disc. The negatives show distinct halos around the disc of the sun. Photographs illustrate the paper.—*Comptes Rendus*, No. 12, 1905, pp. 768–778. J. T.

12. *Kristallinische Flüssigkeiten und Flüssige Kristalle*; von Dr. RUDOLF SCHENCK. 159 pp., 8vo, with 86 figures in the text.—The highly important work of Lehmann on “Flüssige Kristalle” was published a year ago and presented a large array of interest-

ing and novel phenomena in regard to liquids, which under certain conditions exhibit the phenomena of double-refraction. The present volume is a further contribution to the same remarkable subject in which the observations of the author and his associates, particularly as the physico-chemical properties of the liquids, are given in detail. These phenomena, in general, are exhibited through a definite interval of temperature included between the point of fusion and the "Klarungs-punkt," or that at which the transition to the transparent isotropic fluid takes place. The chapter discussing in detail the properties of these two points, their relation to the density, their dependence upon the pressure, upon the presence of foreign constituents and other related points is of great interest. Another chapter not less important, treats of the viscosity and other properties of the "crystalline" and isotropic fluids. The author wisely makes free use of the work of Lehmann and by this means is enabled, in a limited space, to present an excellent summary of the entire subject.

13. "*N*" Rays: *A Collection of Papers communicated to the French Academy of Sciences with additional Notes and Instructions for the Construction of Phosphorescent Screens*; by R. BLONDLOT; translated by J. GARCIN. Pp. xii, 83; with phosphorescent screen (frontispiece) and other illustrations. London and New York, 1905 (Longmans, Green & Co.).—The subject of the "*N*"-rays* is one that has excited much attention, although there have been some to raise the question as to the objective reality of the phenomena described. In any case, however, it is a matter of great interest to have the original papers of Professor Blondlot translated and brought together in a single volume; this work has been well done by M. Garcin. Fifteen papers are included, all reprinted as they were originally published in the *Comptes Rendus* of the French Academy. A number of plates are introduced which show the phenomena described, and the frontispiece consists of a phosphorescent screen of calcium sulphide for use in the observation of the "*N*"-rays, and prepared in accordance with the methods described in the closing pages of the volume.

14. *Das elektrische Bogenlicht, seine Entwicklung und seine physikalischen Grundlagen*; von W. B. VON CZUDNOCHOWSKI, Zweite Lieferung, pp. 99–194; dritte Lieferung, pp. 195–290. Leipzig, 1905 (S. Hirzel).—The second and third parts of this exhaustive work on the electric arc-light, announced in an earlier number of this Journal, have recently been issued. These are largely devoted to a historical discussion of the development of the arc-light from the time of Volta and Davy down to 1900. The subject has now reached so definite and relatively simple a stage that it is interesting to recall the many and varied attempts to solve the problems which had to be made before success was

* Named in allusion to the city (Nancy) at the university in which the author is professor.

finally attained. The prominent forms of regulators, devised from time to time, are described fully and in historical order. The various special problems which have arisen, as the division of the electric light, the application of the light for signals at sea, the relation of light intensity to distance of visibility, and so on, are also treated in detail. The three parts now issued complete about one-half of the work as planned.

15. *The new Knowledge: A popular Account of the new Physics and the new Chemistry in their Relation to the new Theory of Matter*; by ROBERT KENNEDY DUNCAN. 263 pp., 8vo. New York, 1905 (A. S. Barnes & Co.).—There is no reason why, at the present day, the intelligent laymen should not acquire a reasonably good knowledge of the progress that is being made in the different branches of science, for books are not wanting which put before him the facts in a form requiring a minimum of preliminary training. The volume at hand is one having this object, but its scope is broader than usual, and the nature of matter, as now understood, and the light thrown upon the subject by the phenomena of electricity and radio-activity are presented with much system and clearness, and with a style to attract the reader. The closing chapters reach out beyond the earth to some of the problems of the stellar universe.

16. *Percentage Tables for Elementary Analysis*; by LEO F. GUTTMANN, Ph.D. 43 pp. 8vo. New York and London, 1904 (Whittaker & Co.).—These tables, reproduced here from the German edition, will be found most useful by the practical chemist, as they give him at once with all necessary accuracy (to four decimal places), from the amount of carbon dioxide and water yielded on combustion by the substance under examination, the percentage of carbon and hydrogen which it contains. A proportional table opens the volume and one for the reduction of volumes of nitrogen to grams is added at the end.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey*, CHARLES D. WALCOTT, Director.—The following publications have been recently received; notices of some of them are deferred to a later number.

GEOLOGIC FOLIOS. No. 117. Casselton-Fargo Folio, North Dakota-Minnesota; by C. M. HALL and D. E. WILLARD.

No. 118. Greeneville Folio, Tennessee-North Carolina; by ARTHUR KEITH.

No. 119. Fayetteville Folio, Arkansas-Missouri; by G. I. ADAMS and E. O. ULRICH.

PROFESSIONAL PAPERS. No. 32. Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains; by N. H. DARTON. 433 pp. 4to, 72 plates, 18 figures.

No. 39. Forest Conditions in the Gila River Forest Reserve, New Mexico; by THEODORE F. RIXON. 89 pp. with folded map and diagram.

BULLETINS. No. 238. *Economic Geology of the Iola Quadrangle, Kansas*; by G. I. ADAMS, E. HAWORTH and W. R. CRANE. 80 pp., with 11 plates, 13 figures.—The Iola Quadrangle embraces an area of 944 sq. miles in the southeastern portion of Kansas. It lies in the prairie plains region characteristic of the eastern portion of the state, and is of especial interest because of its extensive oil and gas resources. The geological structure and relations of the oil and gas are in general similar to those prevailing over the entire Kansas-Indian Territory field, and hence the facts brought out in this bulletin, which is issued in advance of the Iola folio now in preparation, will be found useful by those interested in other portions of the field.

Briefly stated, the rocks exposed by outcrops and revealed by the drillings belong to the Pennsylvanian series of the Carboniferous. This series, known as the Coal Measures, contains beds of workable coal chiefly in the lower portions; the Boone limestone of the Mississippian series lies below the Coal Measures. The oil and gas of the region are largely confined to the Cherokee shales, which here form the lowest section of the Coal Measures and have a thickness of some 450 feet. The oil and gas reservoirs are associated with beds of sandstone, of varying extent and thickness, and sometimes of very local extent. Many facts of an economic importance are brought out in the bulletin, particularly with reference to the gas wells. This region also affords considerable quantities of Portland cement and there are important brickmaking plants.

No. 242. *Geology of the Hudson Valley between the Hoosic and the Kinderhook*; by T. NELSON DALE. 63 pp., 3 plates including a geological map, 17 figures.

No. 246. *Zinc and Lead Deposits of Northwestern Illinois*; by H. FOSTER BAIN. 56 pp., 5 plates, 3 figures.—The region covered by this paper lies in the extreme northwestern portion of the state, including a part of Jo Daviess county. Another region, also yielding zinc and lead minerals, is found in the southern portion of the state (in Hardin, Pope and Saline counties) and forms part of the Kentucky-Illinois fluorspar, lead and zinc field. The former region, here described, has been known to yield lead since 1700 and mining operations have been carried forward for upwards of one hundred years. Much has been written by different authors as to the mineralogical nature of the deposits, the method of their occurrence and their origin; the present paper gives a convenient and concise summary of the facts as now known, upon what the writer's observations have served to throw additional light.

No. 249. *Limestones of Southwestern Pennsylvania*; by FREDERICK G. CLAPP. 52 pp., 7 plates.—The subject developed in this paper is the character and distribution of limestones suitable for Portland cement, or for other economic uses. Sixteen layers of limestone are recognized and named, varying in thickness from 60 to 6 feet; the occurrences are described and the prospective value of each estimated.

No. 250. The Petroleum Fields of the Pacific Coast of Alaska with an account of the Bering River Coal Deposits; by GEORGE C. MARTIN. 64 pp., 7 plates, 3 figures.—The observations made thus far are preliminary only, but they serve to show that at several points on the Alaska coast, conspicuously near Controller Bay, about 100 miles west of Mt. St. Elias, petroleum occurs in some quantity, and the region may prove to be an important source in the future; explorations thus far made are, however, inconclusive. The best coal thus far found on the Pacific coast is that of Bering river which flows into Controller Bay. Petroleum fields have also been somewhat developed on the western shore of Cook Inlet and on Cold Bay opposite Kodiak Island.

No. 252. Preliminary Report on the Geology and Water Resources of Central Oregon; by ISRAEL C. RUSSELL. 138 pp. 24 plates, 4 figures.—This bulletin gives, as the result of a rapid reconnoissance, an interesting and well illustrated account of a little known region in central and eastern Oregon. It includes the extreme northern part of the Great Basin, which has no external outflow, and also a part of the drainage area of the Deschutes and Crooked rivers. Much of it is an arid region, conspicuously the "Great Sandy Desert," which has a length of 150 and a width of 30 to 50 miles. Of the hills or mountains of the region, much the greater number owe their origin to volcanic eruptions, the cones being particularly abundant to the west in the neighborhood of the Cascade Mountains. The volcanic rocks are mainly rhyolites, andesites and basalts, the last named being in general the latest, though certain andesites and andesitic tuffs are the youngest of all the lava outflows. In the west-central part of the state an extensive shell of pumice, similar to that about Crater lake described by Diller, forms a thick mantle over the surface. The sedimentary formations consist of soft, or partially consolidated beds, of Tertiary age. Interesting observations, with excellent views, are given of the present glaciers, particularly on the three peaks of the Cascade Mountains known as the Three Sisters. In regard to the extent of former glaciation the writer states "that during a former period, which can be safely correlated with the Glacial epoch, great snow fields covered the summit portion of the Cascade Mountains throughout their entire extent across Oregon, and from this névé region large alpine glaciers flowed eastward down the mountains. Glaciers also occurred on the west side of the range, but no new facts concerning them can be presented at this time. The conditions were of the same general character as existed on the Cascade Mountains in Washington, but the eastward-flowing ice streams were seemingly less extensive. An instructive suggestion in reference to the glaciers on the east side of the Cascade Mountains in Oregon is furnished by the fact that in the southern portion of the state, in the vicinity of Mounts Scott and Mazama, the eastward-flowing glaciers are larger and of greater length than farther north in the vicinity of the Three Sisters peaks and

Mount Jefferson. If this conclusion is sustained by future studies, an explanation of it will perhaps be suggested by comparing the present climatic conditions of the two regions."

No. 258. *The Origin of certain Place Names in the United States* (second edition); by HENRY GANNETT. 334 pp. This paper is a second edition of that published as Bulletin No. 197; it contains a large amount of useful geographical information.

No. 259. *Report on Progress of Investigations of Mineral Resources of Alaska in 1904*; by ALFRED H. BROOKS and others. 196 pp., 3 plates, 10 figures.—This bulletin gives an account, by the different geologists at work, of the information gathered during the last season in regard to the various mineral deposits of Alaska. Nine parties were in the field, five of them engaged in geologic work, two in topographic surveys, one was a combined geologic and topographic party and one studied the methods and costs of placer mining. The larger part of the bulletin is devoted to the gold placers, but an account is also given of the Treadwell ore deposits on Douglas Island, as, too, of the recent development of tin deposits in Alaska. Further, the coal and petroleum resources of Alaska are discussed in detail (see also Bulletin No. 250).

No. 261. *Preliminary Report on the Operations of the Coal-testing Plant of the U. S. Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904*; E. W. PARKER, J. A. HOLMES, M. R. CAMPBELL, Committee in charge. 192 pp.

No. 264. *Record of Deep Well Drilling for 1904*; by M. L. FULLER, E. F. LINES and A. C. VEATCH. 106 pp.—The work of the Survey, in regard to the accumulation of geological and physical data of deep wells, although only recently inaugurated, is now so well organized that a very large amount of useful material is promptly brought together and given to the public. The paper now issued is the first of the series planned and presents the material received during the first six months of the work. A tabular summary is given for 358 wells and detailed records are added of a number of selected cases yielding information of importance.

WATER-SUPPLY PAPERS. No. 109. *Hydrography of the Susquehanna Drainage Basin*; J. C. HOYT and R. H. ANDERSON. 210 pp.

No. 111. *Underground Waters of Washington*; HENRY LANDES. 85 pp.

No. 113. *Disposal of Strawboard and Oil-well Wastes*; R. L. SACKETT and I. BOWMAN. 52 pp.

No. 114. *Underground Waters of the Eastern United States*; MYRON L. FULLER. 285 pp.

No. 115. *River Surveys and Profiles made during 1903*; arranged by W. C. HALL and J. C. HOYT. 115 pp.

No. 116. *Water Problems of Santa Barbara, California*; J. B. LIPPINCOTT. 99 pp.

No. 117. *Lignite of North Dakota and its Relation to Irrigation*; by F. A. WILDER. 59 pp.

No. 120. Bibliographic Review and Index of Papers relating to Underground Waters, U. S. Geol. Survey, 1879-1904; by MYRON F. FULLER. 128 pp.

No. 121. Preliminary Report on the Pollution of Lake Champlain; by M. O. LEIGHTON. 119 pp.

No. 122. Relation of the Law to Underground Waters; by D. W. JOHNSON. 55 pp.

2. *Contributions to Devonian Paleontology*; by H. S. WILLIAMS and E. M. KINDLE. Bull. U. S. Geol. Surv., No. 244, 1905, pp. 1-144.—The purpose of this Bulletin is to present the evidence regarding "the nature of the changes in sedimentation, in fossils and in sequence of faunas southward along the Devonian formations in the southern Appalachians." The Devonian sections of the Falls of Ohio region, of southwestern and central western Virginia, east-central Kentucky, and West Virginia, are analyzed and compared with one another. Then the upper Devonian sections in central and northern Pennsylvania are compared with those of New York. This Bulletin will have lasting value because of the many sections it describes in detail and the many faunules listed.

The fossils from the Helderbergian and Oriskanian horizons in Virginia and West Virginia led Professor Williams to conclude "that the subdivisions of the Rensselaeria fauna [Helderbergian and Oriskanian], which in the northern Appalachian region have determined the division of the strata into numerous separate formations, are not universal. Future investigations probably will show that the composition of the local faunules is determined rather by environmental conditions recorded by the differing characters of the sediment than by actual epochs in their history" (p. 49). The present writer will state that he has collected at nearly all of the southern localities described in this Bulletin and at many others, and finds no great difficulties in correlating any one of the southern faunules with the minor horizons of the New York Helderbergian, and this irrespective of the nature of the sediments. In regard to a complete Oriskanian development New York is a poor standard, whereas the Cumberland region is far better. Combining the New York and Maryland sections, the writer is able to state that the New Scotland, Coeymans, and Manlius occur at Big Stone Gap, Va. The "faunule of zone 2 of section 1376 A" and 1376 B2, on p. 28, are unmistakably New Scotland and not "Oriskany." On the "coarse sandstone" rests the Chattanooga Black shale. No Oriskany was seen about Big Stone Gap. To the northeast, near Bluefield, W. Va., there may be a little Lower Oriskany, but in the region of Covington, Va., there probably is not less than 35 feet of typical or Upper Oriskany. At the Low Moor Iron Co. mines, the writer collected *Spirifer arenosus*, *Meristella lata*, *Rensselaeria* sp. undet., *Eatonia singularis*, *Leptaena rhomboidalis*, and *Diaphorostoma ventricosa*.

There is considerable evidence of an erosion interval in the

southern Appalachians before the Black shale invasion, for in the region of Covington, Va., this may be seen resting at times on the Oriskany or the Becraft limestone, which is very well developed here. About Cumberland, Md., the maximum thickness for the Oriskany is about 300 feet. In sections only a few miles apart the thickness will vary from this down to 50 feet, and these thinner sections always carry a Lower Oriskany fauna, indicating a land interval here subsequent to the Upper Oriskany and before the Marcellus. The writer knows of no typical Onondaga (Corniferous) faunas south of northeastern Pennsylvania, and the faunules listed in this Bulletin, as, for instance, 1382 B3 and 1383 A2 and 3, are decidedly more Marcellus than Onondaga. Owing to the irregular pre-Marcellus erosion producing an uneven topography, it follows that the invading base of the Black shale will be different in different places. It is the writer's working hypothesis that owing to the Onondaga erosion interval and the low-lying fold which delimited the western boundary of the Cumberland Basin, the base in different localities may be anywhere between basal Marcellus and the higher Devonian. The Helderbergian and Oriskanian deposits are in full development in Maryland, but thin out rapidly southward, and none attain very far south of the Tennessee-Virginia boundary line. The Manlius, Coeymans, and New Scotland are typically present as far south as Hancock county, Tenn. The Becraft is in full force about Covington, Va., but is gone before Big Stone Gap is reached. The Lower Oriskany is present in the Hicksville, Va., faunule 1379 A1, but no Upper Oriskany. In other words, the waters of the Cumberland Basin extend from Hancock county, Tenn., north into Pennsylvania, throughout Manlius, Coeymans, and New Scotland time. With the Becraft there begins an emergence at the south, slowly dissipating the sea to the north, so that Oriskany sediments do not appear much south of Covington, Va. In Maryland the sea is continuous from the early Silurian to the end of Oriskany time, when emergence also sets in here and affects the Appalachian trough as far north as northeastern Pennsylvania.

Along the eastern side of the Cincinnati axis the invading Black Shale is never older than the Genesee. Here, again, the base is variable, but apparently is always within the time of the Genesee. This variability is due not only to the erosion unconformities pointed out by Dr. Kindle, but also to the transgression of the Genesee sea upon the Cincinnati axis.

Several species of the *Buchiola speciosa* (= *B. retrostriata*) fauna have their first appearance in the Marcellus and are apt to recur throughout the higher Devonian whenever the Black shale conditions prevail. Most of its species have a long range, as may be seen from the table on pp. 51, 52, of this Bulletin. Here 25 species are positively identified. If *Anoplothecca acutiplicata* occurs in this fauna in Virginia (can it be a *Vitulina*?) no particular time value can be assigned to it against the 24 other asso-

ciated forms, none of which are known to appear before Marcellus time. It therefore seems to the writer unwarranted to conclude, as does Professor Williams, that "the black shales range from as low as the Onondaga." Admitting this identification, then, not only does the form in question persist into Marcellus or later time, but there are, as is well known to Professor Williams, many other Onondaga species persisting into Hamilton time in other faunules than those listed in this Bulletin (*Chonetes mucronatus*, *Pentagonia unisulcata*, *Parazyga hirsuta*, *Rhipidomella vanuxemi*, *Spirifer acuminata*, etc.). With these facts in view, it does not follow that the Black Shale ranges "from as low as the Onondaga." The *Buchiola retrostriata* fauna is a puzzle to stratigraphers other than Professor Williams. It comes to America as a migrant along an unknown path (there are three possibilities), appearing in part first in the Marcellus, recurring always with the Black shale conditions, and evidently is finally made up of other later migrants and stragglers from the American Hamilton faunas.

The sections and faunal lists of "Devonian sections in Central and Northern Pennsylvania" are given in great detail and have an especial value in connecting the type area of New York with the middle and southern Appalachians. For the first time, here is found a carefully collected sequence of Upper Devonian faunules; also the relation of the Catskill formation to the Chemung of Pennsylvania.

In conclusion, the writer will state that it is not shown that stratigraphers can not rely upon the fossil assemblages, as presented in these faunules, for definite correlation of formations over wide areas and especially within faunal provinces. The top and bottom of the correlated formations may not be everywhere exactly contemporaneous, yet for practical purposes they are fairly exact. It is true that the faunules are ever changing and that they are controlled to some extent by the character of the sediments (in some cases very largely so, and this is particularly true of the Black shale condition), but in nearly every faunule this constant change preserves a something by which its time position can be recognized. At times this something is the presence of a certain species, the dominance of a certain few species, the assemblage or absence of a certain species, controlled by the stratigraphic position of the faunule. It is known that many of the New York Hamilton Bryozoa and Ostracoda occur at the top of the Onondaga in the Falls of Ohio region, and Dr. Clarke has suggested that the top of the Onondaga limestone in New York probably is a tangential horizon, one end of which lies in Onondaga, the other in Marcellus time. Features further complicating these Devonian faunas, and to which but very few paleontologists have given attention, are the sources of the faunas, the paths of migration, and the barriers or low anticlines that originated at different times in the American Paleozoic epicontinental seas, resulting from Appalachian and Arkansas-Oklahoma movements.

Some conclusions resulting from the work recorded in this Bulletin are set forth by Professor Williams in another paper entitled "Bearing of some new paleontologic facts on nomenclature and classification of sedimentary formations" (Geol. Soc. Amer., 1905). His conclusions are at variance with the experience of other paleontologists, a fact clearly brought out in a recent discussion by the paleontologists of the U. S. Geological Survey (Stanton, Dall, Ulrich, and White) and summarized in Science, April 14, 1905 (pp. 583-585).

CHARLES SCHUCHERT.

3. *Structure of some Primitive Cephalopods*; by R. RUEDEMANN. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 296-341, pls. 6-13.—This very important and highly instructive paper treats in the main of the structure and development of *Endoceras brainardi* of the lowest Ordovician of the Lake Champlain region. It is shown that this primitive cephalopod begins with a protoconch followed by a long, gradually tapering, rather large and non-septate cone, as in Nanno and Vaginoceras. After attaining a length of about 70^{mm}, a slight constriction of the cone takes place and at this point it may be said that the wall of the cone divides, the inner division (or conchiolinous portion) to continue as the wall of the siphuncle (a continuation of the original cone cavity), while between it and the outer calcareous wall is developed the camerated space, or phragmocone. Within the siphuncle, after a few of the cameræ have been developed, there then appear other cones, the endocones, which communicate with one another by means of a central canal, or "endosiphuncular canal." The wall of the siphuncle rests against the recumbent edges of the cameræ walls until within a few inches of the terminal growth, where the cameræ (or "septal necks") form the lining to the large siphuncle opening directly into the living chamber. There are further siphuncular complicating structures about the endosiphuncular canal too complicated to be given here in a few words. However, it should be added that these developments led the author to a comparison of these structures with the Belemnites, and he concludes that the "endosiphocoleon" of endoceroids and the proöstracum in the Belemnites are "formed in identical places," i. e., "within a mantle flap or fold situated at the posterior end of the animal."

The author then discusses various early endoceran genera and concludes that the genera Cameroceras (syn. Endoceras) and Vaginoceras have earlier generic types for which he proposes Proterocameroceras and Proterovaginoceras. The latter is considered to contain the radical stock for these primitive forms. As Piloceras is closely related to these genera, the author also studied the development of this genus in *P. explanator*. From a study of this form he concludes that there is also here an earlier type with an external primitive cone, as in Proterocameroceras. To this very interesting but as yet undiscovered form, he gives the generic name Proteropiloceras, which of course no one is obliged to accept, under the rules of nomenclature. *Piloceras*

newton-winchelli Clarke is shown to be an Orthocerocone retaining Endocerocone structures, and is made the genotype of a new genus. This animal, therefore, bears the long and barbaric name *Clarkoceras newton-winchelli*. C. S.

4. *Notes on the Siluric or Ontario section of Eastern New York*; by C. A. HARTNAGEL. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 342-358.—This paper gives a clear exposition of the late Siluric deposits of southeastern New York and their correlation with the same horizons of the western part of the state. It is established that these deposits were laid down in two contemporaneous seas, a western or Mississippian sea and an eastern basin, the Cumberland. At times some of the species are common to the two waters, but as a rule each has its distinct fauna.

The Shawangunk, heretofore accepted as basal Siluric, is shown to be probably the basal or invading Salina sandstone in the Cumberland Basin. C. S.

5. *The Trilobites of the Chazy Limestone*; by PERCY E. RAYMOND. Ann. Carnegie Mus., III, 1905, pp. 328-386, pls. 10-14.—During the past five summers, Mr. Raymond has been studying the Chazy in the field, and here are presented his first laboratory results. All the known Chazy trilobites are described, 35 in number, of which 18 are new to the Chazy formation. A new subgenus *Glaphurus* is proposed. The genus *Ceraurus* is restudied, and the species referred to four divisions—*Ceraurus*, *Sphaerocorphe*, *Pseudosphærezochus*, and *Nieszkowskia*. This paper should be studied in connection with one by the same author in the May number of this Journal.

The author brings out the interesting fact that the four orders of trilobites into which the class is divided are present in this old Ordovician fauna; further, that the Chazy trilobites are closely related to those of the Trenton, and that three species are common to the two formations. With the Beekmantown below, there is far less agreement. C. S.

6. *Contributions to the Fauna of the Chazy Limestone on Valcour Island, Lake Champlain*; by GEORGE H. HUDSON. Rept. N. Y. State Pal., 1903 (April, 1905), pp. 270-295, pls. 1-5.—This is the first paleontologic publication of Professor Hudson, and describes 1 new cystoid, 3 crinoids, 2 brachiopods, 2 pelecypods, 6 gastropods, and 1 trilobite. C. S.

7. *Ueber Pteraspis dunensis* F. Roem. sp.; by F. DREVERMANN, in Marburg. Zeitschr. Deut. geol. Gesellsch., 56, 1904, pp. 275-289, pls. 19-21.—A very important paper on this Lower Devonian fish, based on many specimens recently discovered at Hamm, on the river Sieg, by Dr. Drevermann. C. S.

8. *Notice of a new Crinoid and a new Mollusk from the Portage rocks of New York*; by R. P. WHITFIELD. Bull. Amer. Mus. Nat. Hist., 21, 1905, pp. 17-20, pls. 1-4.—The crinoid is *Maragnicrinus portlandicus*, genus and species new. *Onychocardium portlandicum* is the new genus and species of bivalve. Remarks are also made on *Cyathocrinus ornatissimus*, which the author refers to *Cosmocrinus*. C. S.

9. *Fossils of the Bahama Islands, with a list of the non-marine mollusks*; by W. H. DALL. (The Bahama Islands, edited by G. B. Shattuck. See 12, below.) Geogr. Soc. Baltimore, 1905, pp. 23-47, pls. 11-13. In this paper are described a number of new species. The list of Bahama land shells, recent and fossil, has 171 species and varieties. Of marine fossil mollusks there are 51 species. The fauna of the "salt pans" has 12 species, of which 6 are peculiar to these lagoons. C. S.

10. *On the Relations of the Land and Fresh-water Mollusk-fauna of Alaska and Eastern Siberia*; by W. H. DALL. Popular Sci. Monthly, Feb., 1905, pp. 362-366.

11. *Geological Survey of Ohio*, Edward Orton, Jr., State Geologist. Fourth series, Bulletin No. 3. *The Manufacture of Hydraulic Cements*; by A. V. BLEININGER. Pp. xiv, 391. Columbus, Ohio, 1904.—The author has brought together in this volume a large amount of information relating to the different materials suitable for Portland cement and the methods of their manufacture. Much of the matter here given has not hitherto been accessible in English books. Attention is given particularly to the chemical side of the subject and the writer contributes also the results of his own researches.

12. *The Bahama Islands*. 630 pp. 93 plates. 7 figures. New York, 1905. (The Macmillan Company.)—This elaborate volume on The Bahama Islands is the product of an expedition of the Geographical Society of Baltimore, led in 1903 by Prof. Geo. B. Shattuck. Much assistance was received from several governmental Bureaus in Washington as well as from Johns Hopkins University in the way of instrumental and other outfit for the expedition. The volume treats the islands in all their aspects, scientific, hygienic, historic, economic; no less than fifteen authors contribute to its pages. The presence of water-filled caves to a depth of 300 feet and the discovery of recent bedded deposits with abundant marine fossils at heights up to 10 or 15 feet above sea-level in certain islands are taken to indicate former higher and lower stands of the land. Marine erosion, as well as preponderating submergence, is held responsible for the great diminution of a much larger former land area. The variety of soils, as indicated on soil maps of several islands, is greater than might be expected on a foundation of limestone alone. Pine-apples are the most important agricultural product; in some plantations they are grown in the little pockets weathered in the limestone surface. The history of the islands, with special regard to slavery, is given in detail. It was reported after the Baltimore conflagration that the Geographical Society was seriously affected by that disaster; but the issue of this handsome volume leads us to hope that the Society has only been temporarily affected, and that it will soon regain the vigor with which its career was begun. W. M. D.

13. *La Montagne Pelée et ses Éruptions*; by A. LACROIX. 4to. Paris, 1904 (Masson et Cie).—In this imposing and beau-

tifully illustrated volume, which is published by the Académie des Sciences of Paris, Prof. Lacroix, the chief of the French Scientific Commission sent to investigate the phenomena of Pelée and the general conditions attending the destruction of Saint-Pierre, presents his final report on his observations. This is the most extended study that has yet been made of the cataclysm of May, 1902, and of the volcanic phenomena of the island that followed upon this remarkable outburst. Much of what the volume contains has already appeared in advance papers published in the *Comptes Rendus*, and the conclusions advanced have also in large part been anticipated, both by the author himself and by the foreign investigators who preceded Lacroix in their investigations, but for all that the work stands as one of the finest contributions to vulcanology which geological literature contains, and it is to be hoped will be made a measure for future exploratory work of the same kind that may be initiated. On the main points connected with the now historic cataclysm, Prof. Lacroix holds generally to the views that have been advanced by the American investigators. The destroying blast of May 8 was an explosion of steam, with other gases, directed initially downward from the ancient crateral spot of the volcano, the Étang Sec, and has in kind been repeated a number of times since (the *nuées ardentes*), as on May 20, June 6, July 9, Aug. 30 (destruction of Morne Rouge) and other periods. Heated to a very high temperature, which may have reached 1500° to 2000° or more, densely charged with volcanic debris that it carried in its train, and descending with a velocity which at its point of impact with the unfortunate city is estimated to have been not less than 400 to 450 feet per second, it is not difficult to comprehend why the destruction should have been so absolute and far-reaching. In attributing the descent of the destroying "black cloud" to an initial explosive discharge whose direction was downward, and not to the attractive force of gravity, Lacroix stands in accord with virtually all the American investigators, and opposed to Drs. Flett and Tempest Anderson, representing the Commission of the Royal Society of London. The author is inclined to the belief that Saint-Pierre was annihilated in the space of a single minute, or perhaps even within a fraction of this time. As regards the construction of the remarkable Peléan excrescence which has been at various times described as "spine," "tower," "obelisk," and "needle," and which at its greatest development rose above its supporting dome by upwards of 1000 feet, Lacroix holds to his original views, somewhat modified in its details, that it represented a rapidly solidifying highly viscous (andesitic) lava, whose upward movement was conditioned by almost instantaneous solidification, and the impossibility under such conditions of taking the downward course of ordinary lava-streams. However much one may feel disposed to differ from this conclusion, the observations which have led to it are carefully stated, and form not the least important part of the work. A large part of

the volume is taken up with petrographical research, the author's own particular field of inquiry, which gives an interesting and most important vista into the theory of the formation of quartzitic rocks and the occurrence of free quartz in volcanic magmas.

ANGELO HEILPRIN.

Philadelphia, April 22, 1905.

14. *Recherches géologiques et pétrographiques sur l'Oural du Nord*; par L. DUPARC et F. PEARCE. Mem. Soc. Phys. d'Hist. Nat. Genève, vol. 34, fas. 5, pp. 383-602. Pls. and map. 1905.—The first portion of this work was published in 1902 (ibidem, pp. 57-218) and gave a general description of the portion of the region in the Urals which had been studied (Rastesskaya and Kizelowskaya-Datcha, Govern. Perm.) Different parts of the area were then taken up in detail, the geology described and the petrography of the igneous rock formations presented, accompanied by numerous analyses. In the second memoir these detailed descriptions are continued, studies of the crystalline schists are also given, and the work concludes with observations on the structural geology and summations of the results obtained.

The chief interest centers on the masses of igneous rocks which have been investigated in the field and laboratory; they are chiefly of basic ferro-magnesian types, gabbros, dunites and pyroxenites. Of the latter a special type is described consisting of a foliated pyroxene with a variable amount of olivine and magnetite; the texture is granitic; the magnetite, playing the same role as quartz in a granite, forms the cement to the other minerals. To this rock the name of *kosvite* is given. To another type which contains a certain amount of feldspar rich in lime, but which differs chemically from the gabbros, the name of *tilaite* is given.

The work is enriched by many figures and half-tones in the text, and is not only an important and valuable contribution to our knowledge of the Urals, but contains much in addition that is of general interest to geologists and petrographers L. V. P.

15. *Einleitung in die chemische Krystallographie*; von P. GROTH. Pp. 80, 8vo. Leipzig, 1904 (Wilhelm Engelmann).—The author of this little volume has made so many important contributions to the subjects of Mineralogy and Crystallography, both separately and in their mutual relations, that it will not be a matter of surprise that the present volume, although brief in extent, is very helpful and suggestive in regard to the various topics it discusses. Its object, briefly stated, is to present the relations which exist between the properties of crystallized bodies and their chemical constitution as based upon a definite theory as to the structure of crystals. It is, moreover, introductory to an exhaustive work in preparation by the author, in which it is proposed to give a systematic and critical presentation of crystal forms and the physical properties of crystallized substances.

16. *Grundzüge der Krystallographie*; von Prof. C. M. VIOLA. Pp. x, 389, 8vo. Leipzig, 1904 (Wilhelm Engelmann).—This

volume is based upon the course of lectures which the author has delivered at the University in Rome. The subject, however, has been much expanded and developed, and now presents the Crystallography of the present day as viewed by the author, from a standpoint at once advanced and theoretical. The student whose interests lie in this, rather than in the strictly practical side of the subject, will find this work worthy of careful study.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Ascent of Water in Trees*; by ALFRED J. EWART (abstract of a paper read before the Royal Society of London).—As the result of a series of experimental observations bearing upon this problem, the author has been led to the conclusions stated in brief below.

The flow of water through open vessels filled with sap takes place in accordance with Poiseuille's formula for the flow through rigid cylindrical tubes, divergences being due to the presence of irregular internal thickenings in the vessels, and to local constrictions or deviations from the circular outline.

Hence the velocity of flow is directly proportional to the pressure and to the square of the radius of the tube, inversely proportional to the length of the tube and to the viscosity of the liquid. A small number of large vessels, therefore, offer very much less resistance to flow than a large number of narrow ones having the same length, and the same total internal area of cross-section. Since viscosity is largely dependent upon temperature, the latter forms an important factor in regulating the flow, the viscosity and the resistance falling with a rise of temperature.

With an average rate of flow the total resistance due to the viscosity of the water flowing through the vessels is always less, and in climbing plants with large vessels is considerably less, than a head of water equal in height to the stem. The adult vessels of actively transpiring angiospermous trees always contain air-bubbles, and these introduce a resistance to flow which is inversely proportional to the radius of the tube, when the air-bubbles and the water-columns move together. When the air-bubbles are comparatively stationary, as in most vessels, the resistance is still further increased, and it becomes very great when the vessels are small and the air-bubbles numerous. In intact vessels containing air the rates of flow under similar pressures are proportional to a power of the radius lying between 1 and 2, the volume passing to a power of the radius lying between 2 and 4.

Estimations of the amount of flow, made from the rate of flow and the diameters and number of the vessels, showed that the actual flow takes place in the wood of dicotyledons almost entirely through the cavities of the vessels and hardly at all through the tracheides. In young stems saturated with water under pressure, a considerable flow takes place through the pith, but practically none in intact transpiring stems.

In a cut stem, apart from the blocking at the cut surfaces, a gradual diminution of conductivity occurs along its entire length after water has been passed through for some time. This appears, in part at least, to be due to the development of micro-organisms in the vessels, but may be aided by swelling, by lessened permeability, or by other changes in their walls.

The length of the vessels in the wood of the branches examined averages from 7 to 36 centimeters, the tracheides of the yew being from 0.2 to 0.5 of a centimeter in length. Since, however, the vessels appear mainly to end at the nodes where branches arise, it is possible that they may be much longer in the young wood on old bare trunks. The resistance to transverse flow through saturated wood is 800 to 45,000 times greater than to longitudinal flow, the resistance to filtration under pressure through a single partition wall being from 2 to 10 times greater than that to the flow through the entire length of a vessel filled with water in the wood of a crab apple.

The total resistance to flow in the erect stems of actively transpiring plants appears to correspond to a head of water of from 6 to 33 (shrubs and small trees), or from 5 to 7 (large trees) times the height of the plant. Hence in the tallest trees the total pressure required to maintain active transpiration may be equivalent to as much as 100 atmospheres.

No leaf could produce or maintain an osmotic suction of this intensity, and in the presence of large air-bubbles in the vessels the stress transmitted in them from the leaves could never be as great as an atmosphere. Vines* found, for instance, that the suction force of a transpiring branch was never greater than two-thirds of an atmosphere. The supposition that these forces might summate is entirely erroneous. On the contrary, the leaves at the base of a tree would pull water down from the upper vessels and leaves, instead of up from the roots, in the absence of any pumping action in the stem, and of any root-pressure.

If the air-bubbles in the vessels were exceedingly minute, they might be under a small positive pressure, while the water outside was under a maximal strain of five atmospheres. This would suffice to overcome the resistance offered during active transpiration by 30 to 80 feet of stem, hence the results obtained by Strasburger with dead stems. The maximal osmotic suction exercised by the leaves, as determined by comparing the osmotic pressures during active transpiration of the leaves at the top and bottom of an elm 18 meters high, appears to be from 2 to 3 atmospheres, and is usually less than this. At the same time the total resistance to flow in the trunk of this tree would be from 10 to 12 atmospheres.

It appears, therefore, that to maintain flow, a pumping action of some kind or other must be exercised in the wood, for which the presence of active living cells is essential. In support of

* *Annals of Botany*, 1896, vol. x, p. 488.

this it has been shown that the production of wood in a slowly growing tree is greater than is necessitated by mechanical requirements. In other words, the production of new wood is largely determined by the length of time during which the wood-parenchyma can remain active.

There is no known means by which these cells can directly pump water in a definite direction, although the existence of a power of absorbing and exuding water under pressure has been empirically determined to exist in the living wood of cut branches. It is suggested that the wood-parenchyma cells by the excretion and re-absorption of dissolved materials may bring into play surface-tension forces within the vessels of sufficient aggregate intensity to maintain a steady upward flow, and to keep the water of the Jamin's chains in the vessels in a mobile condition ready to flow to wherever suction is exercised upon it.* The rapid rates of diffusion required for such action do actually exist in the wood-parenchyma cells.

It appears that the terminal branches of trees at heights of from 22 to 44 feet above ground exhibit little or no power of bleeding in spring. Possibly in such trees the pumping action is only used or developed in the wood of the older stems, or is only exercised when transpiration is active, and when the water-columns in the vessels attain a definite size relatively to the wood-parenchyma cells. The importance of the Jamin's chain in the vessels is that it renders a staircase-pumping action possible, and enables the water to be maintained in the vessels in a labile condition, ready to flow to any point where moderate suction is exercised. This pumping action being diffused and probably regulated, need not produce any high pressure of exudation at the terminal branches of tall trees, which, in fact, appears always to be absent at high levels.—*Proc. Roy. Soc.*, lxxiv, 554.

2. *Problems of the Panama Canal*; by Brig.-Gen. HENRY L. ABBOT, U. S. Army, retired. 248 pp. New York, 1905 (The Macmillan Co.).—The position occupied for so many years by General Abbot in the Engineer Corps of the United States Army, and also his official connection with the new French company for the Panama Canal established in 1894, have made him particularly fitted to give an accurate and thorough presentation of the more important scientific problems involved in the present and future work on the Canal. The volume is a particularly timely one, and will be read with interest by the general public, as well as by those more immediately concerned. A brief historical introduction is given, followed by a chapter on the relative advantages of the two routes which have been discussed; to that of Panama unqualified approval is given. The bulk of the work, however, is devoted to the consideration of the peculiar physical conditions existing on the Isthmus, particularly those affecting

* Surface-tension actions would be possible in the absence of air-bubbles wherever the wood-parenchyma cells contained oil or any other substance non-miscible with water, as they often do.

the prosecution of the work. These include chiefly the range of temperature during the different seasons of the year, and still more the amount and distribution of the rainfall; full details with numerous tables are given in both these directions. In connection with the latter subject, the hydraulic problems involved in the regulation of the Chagres River are discussed at length, and with the same thoroughness which characterizes the other parts of the work. The conclusion is reached that although the matter presents serious difficulties, they are not greater than those that have been met with elsewhere, and that "all that is required is a judicious plan of regulation based on well-established principles." With respect to the question that has arisen between a sea-level canal and one provided with a series of locks, the author speaks very emphatically in favor of the latter, on general grounds, as also because of the economy in time and money.

3. *A Primer of Forestry. Part II, Practical Forestry*; by GIFFORD PINCHOT, Forester. 88 pp., 12mo, Washington, 1905 (Bulletin No. 24, Part II, U. S. Dept. of Agriculture, Bureau of Forestry).—This little book, like its predecessor, presents the practical problems of forestry in most clear and attractive form. Indeed, brief as it is, the subject is put before the reader so conclusively that it seems difficult to understand why scientific methods are not everywhere employed in dealing with nature's effort to provide humanity with a lasting supply of useful woods, instead of the short-sighted policy so common in this country. The situation has improved materially since the Department of Forestry was organized, and greater progress through the enlightenment of the public is promised for the future.

4. *Field Operations of the Bureau of Soils, 1903*. Fifth Report. By MILTON WHITNEY, Chief, with accompanying papers by assistants in charge of field parties. 1310 pp., with 3 plates, 61 text figures and 78 maps in separate portfolio case. Washington, 1904 (U. S. Department of Agriculture; Bureau of Soils).—During the season of 1903, a total area of 26,543 square miles was surveyed and mapped by the various parties of the Bureau of Soils; this was divided over 61 separate areas, averaging 437 square miles each, in 37 states and territories. The detailed results of this extensive work are contained in these volumes recently given to the public.

5. *Mechanism*; by S. DUNKERLEY. 408 pp. New York and London, 1905 (Longmans, Green & Co.).—This book, while not designed to be a philosophical treatise on pure mechanism, is valuable for its many and modern applications of various machines. The first two chapters, including the introductory one, discuss the simpler types of machines and shop appliances, as well as combinations of belting and gearing. The more complete study of gearing and gear teeth is left to a later chapter. The geometrical properties of mechanism are next taken up with machines whose interest lies particularly in the paths traced by their parts. Steam engine indicators are conspicuous examples

described in illustration. One chapter embraces velocity-ratio diagrams and approximate solutions of link motions. Valve and steering gears, together with various link motions, are given here to exemplify. Another chapter is devoted to acceleration diagrams, which with the velocity-ratio diagrams, are most important in the study of the dynamics of machines. The subject of toothed circular and non-circular wheels is comprised in the last half of the book. The kinematic conditions which must be satisfied by profiles of teeth and methods mechanical and graphical for determining their shapes are fully given. Problems illustrate the text throughout. For a lecture course on the kinematics of machines this book would make an accompaniment for which it is well adapted.

C. B. R.

6. *British Museum of Natural History: Guide to the Gallery of Birds in the Department of Zoology.* 228 pp., with 24 plates and illustrations. London, 1905.—This guide has been prepared by Mr. W. R. OGILVIE-GRANT, Assistant in the Zoological Department, who has also carried out the arrangement of the collections as now exhibited. An appendix is added on the structure of birds with illustrations of the feathers and skeleton. The numerous full-page plates give reproductions of excellent photographs of actual specimens in the gallery. To those who have not had the opportunity to learn by actual visit the riches of the Museum they will give a good idea of the admirable results attained in the representation of birds in their natural surroundings.

7. *Catalogue of the Lepidoptera Phalaenæ in the British Museum, Vol. V. Catalogue of the Noctuidæ*; by SIR GEORGE F. HAMPSON. Pp. xvi, 634, with plates lxxviii-xcv. London, 1905.—The publication of the fourth volume of this important work was noticed in the number for February, 1904. The present volume embraces the classification of the Hadeninæ, the second of the fifteen subfamilies of the Noctuidæ; 946 species belonging to 78 genera are described. This subfamily is characterized by its trifid neurulation of the hind wing, combined with the hairy clothing of the eyes.

8. *Geographen-Kalender; in Verbindung mit vielen Fachgenossen herausgegeben von Dr. HERMANN HAACK.* Dritter Jahrgang, 1905-1906. 468 pp. Gotha, 1905 (Justus Perthes).—The third issue of this useful calendar contains the good features of its predecessors with some additions and emendations. The address list of geographers and those in allied departments has been much enlarged and made more accurate. The literature of the year 1904 is fully treated, as also the necrology; further, a brief summary is given of interesting events illustrated by a series of sixteen maps. A portrait of Jacques-Elisée Reclus forms the frontispiece.

9. *Publications of the Carnegie Institution.*—The following papers have been recently issued:

No. 23. Heredity of Coat Characters in Guinea-Pigs and Rabbits; by W. E. CASTLE. 78 pp., 6 plates (Papers of Station for Experimental Evolution at Cold Spring Harbor, N. Y., No. 1).

No. 24. *Mutants and Hybrids of the Oenotheras*; by D. T. MACDOUGAL, assisted by A. M. VAIL, G. H. SHULL and J. F. SMALL (Cold Spring Harbor Papers, No. 2). 57 pp.

No. 28. A revision of the Atomic Weights of Sodium and Chlorine; by THEODORE W. RICHARDS and ROGER C. WELLS. 70 pp.—See notice on p. 451.

No. 29. *The Color Sensitivity of the Peripheral Retina*; by JOHN WALLACE BAIRD. 80 pp.

No. 30. *Stages in the development of *Sium cicutæfolium**; by GEORGE HARRISON SHULL. 28 pp. (Cold Spring Harbor Papers, No. 3).

A study of the Conditions for Solar Research at Mt. Wilson, California; by GEORGE E. HALE (Contributions from the Solar Observatory of the Carnegie Institution, Mt. Wilson, California, No. 1). 27 pp.—A careful investigation of the climatic conditions upon Mt. Wilson, near Pasadena, California, shows that it offers very great advantages for astronomical work, particularly in the study of the sun and solar radiation. Professor Hale remarks that he knows "no other site that compares at all favorably with it." It is much to be hoped that the plans for the building and equipment of a large solar observatory at this point may be carried rapidly to completion.

10. *Cold Spring Harbor Monographs*. III, *The Salt-Marsh Amphipod: *Orchestia palustris**; by MABEL E. SMALLWOOD. 21 pp. with two plates and a map. Brooklyn, March, 1905. Published by the Brooklyn Institute of Arts and Sciences.

11. *Science Bulletins of the Brooklyn Institute of Arts and Sciences*. Published by the Macmillan Company—The following numbers of volume I have appeared under date of March 31:

No. 5. *Mammals from Beaver County, Utah*, collected by the Museum Expedition of 1904; by J. A. ALLEN. Pp. 117–122.

No. 6. *Additions to the Coleoptera of the United States with notes on some known species*; by CHAS. SCHAEFFER. Pp. 123–140.

12. *Project for the Panama Canal*; by LINDON W. BATES. 38 pp., with several maps and plans.—The author discusses briefly some of the projects that have been proposed for the canal and then presents in full the one which in his judgment is likely to lead to the best results. General plans and profiles are given of the water way, the regulation works, and the terminal harbors.

OBITUARY.

HENRY R. MEDLICOTT, F.R.S., the eminent English geologist, died on April 6 at the age of seventy-six years. His work was chiefly in connection with the Geological Survey of India, which he joined in 1853 and of which he was the Director from 1876 to 1887.

PROFESSOR PIETRO TACCHINI, the celebrated Italian astronomer, died at Spilamberto, Modena, on the 24th of March, at the age of sixty-seven years.

PROFESSOR OTTO STRUVE, Director of the Pulkowa Observatory from 1862–1890, died on April 14, at the age of eighty-five years.

INDEX TO VOLUME XIX.*

A

- Abbot, H. L.**, Problems of the Panama Canal, 470.
Academy, National, meeting at New York, 92; Washington, 399.
 — Biographical Memoirs, vol. v, 262.
Adams, E. P., absence of helium from carnotite, 321.
Adams, G. I., Iola quadrangle, Kansas, 457.
Agassiz, A., Albatross Expedition to the eastern Pacific, 143, 274, 367.
Agricultural Science, Journal of, 400.
Air, spontaneous ionization of, Wood, 454.
Alaska, coal and petroleum, 458, 459; mineral resources, 459.
Albatross expedition to the eastern Pacific, Agassiz, 143, 274, 367.
Allen, E. T., isomorphism and thermal properties of feldspars, 93.
Alternator, high frequency, Duddell, 390.
American Museum Journal, 262.
Antarctic expedition, Scottish National, 262.
Arc Light, Czudnochowski, 251, 455.
Ashley, R. H., oxidation of sulphites by iodine, 237.
Association, American, meeting at Philadelphia, 92.
Astronomical Observatory, Carnegie Institution, Mt. Wilson, 472; Harvard College, 400; Yale, 203; Yerkes, 203.

B

- Bahama Islands**, 465; fossils of, Dall, 465.
Bain, H. F., Illinois zinc-lead deposits, 457.
Balfour, A. J., new theory of matter, 263.
Barkla, C. G., polarized Röntgen radiation, 391.
Barlow, A. E., Sudbury mining district, Ontario, 331.
Barnett, V. H., new dike at Ithaca, N. Y., 210.

- Barrell, J.**, notice of Van Hise on metamorphism, 251.
Barus, C., distribution of nuclei, produced by the X-rays, 175; large and small coronas, 349.
Bates, L. W., Panama canal project, 473.
Bauer, L. A., Terrestrial Magnetism, 248.
Beebe, S. P., Physiological Chemistry, 196.
Billings meteorite from So. Missouri, Ward, 240.
Bi-prism, interference with, McClellan, 294.
Blake, W. P., iodobromite in Arizona, 230.
Blondlot, "N"-rays, 455.

BOTANY.

- Anemiopsis californica**, Holm, 76.
 Water in trees, ascent of, Ewart, 468.
Brazil, palladium and platinum in, Hussak, 397.
British Museum Catalogues, Orthoptera, Kirby, 332; Birds, Ogilvie-Grant, 473; Lepidoptera Phalaenæ, Hampson, 472.
Bronson, H. L., radio-active measurements, 185.
Brooklyn Institute, science bulletins, 473.
Brown, J., hydrochloric acid, etc., in presence of ferric chloride, 81.
Bureau of Standards, bulletin, 91.
Buxton, B. H., Physiological Chemistry, 196.

C

- Canada**, Geol. survey of, 196, 331.
Canyon Diablo Meteorite, Moissan, 191, 323, 396.
Carabidæ, early stages of, Dimmock and Knab, 264.
Carbonic acid, ultra-red spectrum, Schaefer, 245.
Carborundum in a meteorite, Moissan, 191, 323, 396.
Carnegie Institution, publications, 472.

* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

Chemical Analysis, Manual of, Probst and Smith, 453.
— Engineer, 204.

CHEMISTRY.

Air in blast-furnaces, use of dried, Le Chatelier, 192.
Aluminium, double silicides of, Manchot and Kieser, 243.
Ammonia in water, process for detecting, Trillot and Turchet, 323.
Calcium, metallic, Arndt, 191.
— carbide, use in mining, Guédras, 244.
Carbon and its heat of combustion, Mixter, 434.
— silicide in meteorite, Moissan, 191, 323, 396.
Chloride, nitroxyl, Gutbier and Lohmann, 390.
Chlorine, atomic weight, Richards and Wells, 451.
Copper, double cyanides, Grossman and von der Forst, 244.
Diamonds, experiments in preparing, Moissan, 451.
Electrolytes, electrolysis of solid, Haber and Tolloczko, 198.
Emanium, Giesel, 84.
Europium, Urbain and Lacombe, 243.
Fluorine in wine, determination, Treadwell and Koch, 193.
Gold preparations, color changes in, Kirchner and Zeigmondy, 85.
Helium, absence from carnotite, Adams, 321.
Hydrochloric acid and potassium permanganate, interaction, Brown, 31.
Iodine, atomic weight, Baxter, 243.
Methane, properties of, Moissan, 323.
Nitric acid, gravimetric determination, Busch, 388.
Ozobenzol, Harries and Weiss, 83.
Radio-tellurium, Marckwald, 324.
Radium, see Radium.
Silicon, fluoroform, Ruff and Albert, 244.
Sodium, atomic weights, Richards and Wells, 451.
— hydroxide, production of pure, Küster, 83.
Sulphites, oxidation by iodine, Ashley, 237.
Tantalum, properties of, von Bolton, 388.
Thorium, unity of, Meyer and Gumpertz, 389.

Trisulphoxyarsenic acid, McCay and Foster, 192.
Yttrium and ytterbium in fluorite, Humphreys, 202.
Chemistry, Conversations on, Ostwald, 324.
— Organic, Leffman and LaWall, 325.
— Physiological, Beebe and Buxton, 196.
— School, Avery, 84.
Climatic features in land surface, Penck, 165.
Coast and Geodetic survey, report, 261.
Cold Spring Harbor papers, 473.
Colorado, Radium-bearing springs, Headden, 297.
Colored papers, reflection by, Minchin, 445.
Corona, photograph of solar, Hansky, 454.
Coronas, large and small, Barus, 349.
Crystal drawing, Penfield, 39.
Crystalline fluids, etc., Schenck, 454.
Crystallography, Chemical, Groth, 467; Elements, Viola, 467.
Czudnochowski, W. B. von, Das Elektrische Bogenlicht, 251, 455.

D

Dadourian, H. M., radio-activity of underground air, 16; new form of electrode for lead storage cells, 315.
Daly, R. A., machine-made line drawings, 227.
Davis, W. M., bearing of physiography upon Suess' theories, 265; notice of work on Bahama Islands, 465.
Day, A. L., isomorphism and thermal properties of feldspars, 93.
Day, D. T., Mineral Resources of the U. S., 1903, 260.
Diamond, see Minerals.
Diller, J. S., the Bragdon formation, 379.
Doughty Springs, Colorado radium-bearing, Headden, 297.
Drawings, machine-made line, Daly, 227.
Duncan, R. K., The New Knowledge, 456.
Dunkerley, S., Mechanism, 471.
Duparc, L., Recherches géologiques et pétrographiques sur l'Oural du Nord, 467.
Dutton, C. E., Earthquakes in the Light of the new Seismology, 89.
Dynamics of Particles, etc., Webster, 327.

E

- Earthquake investigations in Japan**, Dairoku Kikuchi, 88.
Earthquakes in the Light of the New Seismology, Dutton, 89.
Earth's surface, projection of the whole, van der Grinten, 357.
Eaton, G. F., notice of *Mastodon humboldtii*, Mexico, 330.
Electric arc light, Czudnochowski, 251, 455.
 — discharges in cooled Geissler tubes, spectra of, Goldstein, 245; in vacuum tubes, James, 194.
 — inertia, Burbury, 325.
 — spark, extinction of, Koch, 194.
 — waves, helium tubes as indicators, Dorn, 454.
Electrode for lead storage cells, new form, Dadourian, 315.
Electrolysis of solid electrolytes, 193.
Electro-magnetic waves in the visible spectrum, Braun, 246.
English medicine in the Anglo-Saxon times, Payne, 263.
Evans, N. N., chrysoberyl from Canada, 316.
Ewart, A. J., ascent of water in trees, 468.
Eye, error of collimation in the human, Hastings, 310.
 — optical constants, Hastings, 205.
 — visual phenomena depending upon optical errors of, Hastings, 401.

F

- Fall**, deviation from free, De Sparre, 391.
Feldspars, isomorphism and thermal properties, Day and Allen, 93.
Forestry, Primer of, Part II, Pinchot, 471.
Fossils, see **GEOLOGY**.

G

- Galvanometer deflections**, Einthoven, 246.
Garcin, J., Blondlot's "N"-Rays, 455.
Gases, Dynamical theory of, Jeans, 328.
 — Experimental study of, Travers, 327.
Geissler tubes, exhaustion by the electric current, Riecke, 194.
 — influence of glass walls of, Gehrcke, 85.

- Geissler tubes**, spectra of discharges in cooled, Goldstein, 245.
Geographen-Kalender, Haack, 473.

GEOGRAPHICAL REPORTS AND SURVEYS.

- Canada**, annual report, vol. xiii, 1900, 196; Sudbury district, 331.
Indiana, 1903, 87.
Iowa, vol. xiv, 1903, 196.
Maryland, 258.
New Jersey, vol. vi, 88.
Ohio, fourth series, bulletin, No. 3, 465.
United States, 25th annual report, 256; monograph, xlvii, 251; geologic folios, No. 117-119, 456; professional papers, No. 31, 257, No. 35, 256, Nos. 32, 39, 456; bulletins, Nos. 238, 242, 246, 249, 457, Nos. 250, 252, 458, Nos. 258, 259, 261, 457; water supply papers, Nos. 109, 111, 113-117, 459, Nos. 120-122, 460.
Vermont, annual report, 395.

GEOLOGY.

- Amphion**, Harpina and Platymetopus, note on the names, Raymond, 377.
Arbuckle and Wichita Mts. of Indian Territory and Oklahoma, Taff and Bain, 257.
Autophytography, White, 231.
Bragdon formation, Diller, 379.
Cambrian Brachiopoda, Walcott, 329.
Canyon of the Hudson River, submarine, Spencer, 1.
Cephalopods, structure of some primitive, Ruedemann, 463.
Chazy limestone, trilobites of Raymond, 464; fauna of Hudson, 464.
Crinoid and mollusk, new, from the Portage rocks of New York, Whitfield, 464.
Devonian Fauna of Kwataboahagan River, Parks, 198.
 — **Paleontology**, Williams and Kindle, 460.
Dike, new, at Ithaca, N. Y., Barnett, 210.
Fossils of the Bahama Islands, Dall, 465.
Geology of Perry Basin in southeastern Maine, Smith and White, 256.

GEOLOGY.

- Glaciation in South Africa, Frames, 197.
 Hyopsodidae, Loomis, 416.
 Lower Silurian in Venezuela, Drevemann, 197.
 Lytoniidae, structure and organization, Noetting, 199.
 Mastodon humboldtii in northern Mexico, Sheldon, 330.
 Metamorphism, Treatise on, Van Hise, 251.
 Mollusk-fauna of Alaska and Siberia, Dall, 465.
 Sedimentary rocks of the Transvaal, Hatch, 258.
 Siluric or Ontaric section of eastern New York, Hartnagel, 464.
 Suess' theories, bearing of physiography upon, Davis, 265.
 Triassic Ichthyosauria, Merriam, 23.
 Trilobites of the Chazy limestone, Raymond, 464.
 Valleys off North America, submarine, Spencer, 341.
 See also **ROCKS**.
 Gilbert, G. K., plans for obtaining subterranean temperatures, 393.
 Glaciation, see **Geology**.
 Grinten, A. J. van der, projection of the earth's surface, 357.
 Groth, P., Einleitung in die chemische Krystallographie, 467.
 Guttman, L. F., Percentage Tables for Elementary Analysis, 456.

H

- Hand, J. E., Ideals of Science and Faith, 263.
 Harrington, B. J., fetid calcite, 345.
 Harvard College, Astronomical Observatory, 400.
 Hastings, C. S., optical constants of the eye for different colors, 205; error of collimation in the eye, 310; visual phenomena depending upon optical errors of the eye, 401.
 Headen, W. P., group of radium-bearing springs, Colorado, 297.
 Heilprin, A., the tower of Pelée, 200; review of Lacroix, La Montagne Pelée et ses Éruptions, 465.
 Helium tubes as indicators of electric waves, Dorn, 454.
 Heusler magnetic alloys, Gumlich, 390.
 Hidden, W. E., mineral research in Llano Co., Texas, 425.

- Hill, H. D., measurement of self-inductance, 149.
 Hillebrand, W. F., red beryl from Utah, 330.
 Hoffman, G. C., souesite, 319.
 Holm, T., anemiopsis californica, 76.
 Hudson River, submarine canyon of, J. W. Spencer, 1.
 Hydrogen, helium, etc., spectra in the ultra-violet, Schniederjost, 85.

I

- Illinois zinc-lead deposits, Bain, 457.
 Indiana geological survey, 87; geological map, Hopkins, 88.
 Ionization of air, Wood, 454.
 Iowa geol. survey, 196.
 Iron-nickel alloys, natural, Hoffmann, 319; Jamieson, 413.
 Irving, E., Starry Heavens, 204.

J

- Jamieson, G. S., natural iron-nickel alloys, awaruite, 413.
 Japan, Beiträge zur Mineralogie von, Wada, 399.
 — Minerals of, Wada, 89.
 — recent seismological investigations, Kikuchi, 88.
 Jeans, J. H., Dynamical Theory of Gases, 328.
 Jeffers Mineral Collection, 204.

K

- Kansas, oil and gas field, 457.
 Kindle, E. M., Devonian Paleontology, 460.
 Knowledge, The New, Duncan, 456.
 Kraus, E. H., celestite-bearing rocks, 286.
 Kreider, J. L., apparatus for determining volatile substances, 188.
 Kristallinische Flüssigkeiten, Schenck, 454.
 Krystallographie, Einleitung in die chemische, Groth, 467; Grundzüge der, Viola, 467.
 Kunz, G. F., Moissanite, 396.

L

- Lacroix, A., Mt. Pelée and its eruptions, 465.
 Lassar-Cohn's General Organic Reactions, translated by J. B. Tingle, 84.
 LaWall, C. H., Text-book of Organic Chemistry, 325.

- Leffmann, H.**, Text-book of Organic Chemistry, 325.
Light, pressure of, Bartoli, 86; Poynting, 458.
 — reflection by colored papers, Minchin, 445.
Line drawings, machine-made, Daly, 227.
Loeb, Studies in Physiology, 264, 332.
Loomis, F. B., Hyopsodidæ, 416.

M

- Magnetic alloys**, production of, Hadfield, 83; Heusler, Gumlich, 390.
Magnetism, Terrestrial, Bauer, 248.
Map projections, van der Grinten, 357.
Martin, G. C., Alaska petroleum and coal, 458.
Maryland geol. survey, 258.
Matter, New Theory of, Balfour, 263.
McClellan, W., interference with the bi-prism, 294.
Mechanism, Dunkerley, 471.
Medicine, English, in Anglo-Saxon Times, Payne, 263.
Merriam, J. C., Triassic Ichthyosauria, 23.
Metals in an electric oven, emission spectra, King, 326.
Metamorphism, Treatise on, Van Hise, 251.
Meteorite, new Billings iron, So. Missouri, Ward, 240.
 — Canyon Diablo, Moissan, 191; carbon silicide in, Moissan, 191, 323, 396.
Minchin, H. D., reflection of light by colored papers, 445.
Mineral collection, Jefferis, 204.
 — research in Llano Co., Texas, Hidden, 425.
 — Resources of the U. S., 1903, Day, 260.
Mineralogy, Crystallography, etc., Moses and Parsons, 261; of Japan, Wada, 89, 399.

MINERALS—

- Albite**, 116. **Anorthite**, 107; Japan, melting point, 260. **Awaruite**, 413.
Beryl, red, Utah, 330.
Calcite, fetid, 345. **Carnotite**, absence of helium in, 321. **Celestite**, occurrence, Kraus, 286.

- Chrysoberyl**, Canada, 316. **Chrysolite**, melting point, 260. **Cyrtolite**, Texas, 431.
Diamond, artificial, 451; in meteorite, 191, 398; from the Transvaal, "Cullinan," 395. **Dumortierite**, 211.
Feldspars, isomorphism and thermal properties, Day and Allen, 93. **Fergusonite**, Texas, 430.
Fluorite, yttrium and ytterbium in, 202.
Gadolinite, Texas, 425.
Hamlinite, Brazil, 202.
Iodobromite, Arizona, 230.
Lepidolite, crystallography, 225. **Leucite**, melting point, 260.
Mackintoshite, Texas, 429. **Moissanite**, 396.
Naëgite, Japan, 90. **Nickel** and copper deposits of Sudbury, Ontario, Barlow, 331. **Nivenite**, Texas, 429.
Palladium, Brazil, 397. **Palmerite**, Italy, 90. **Platinum**, Brazil, 397.
Quartz, replacement by pyrite, Smyth, 277.
Souesite, Canada, 319.
Teallite, Bolivia, 90. **Tengerite** (?) Texas, 431. **Thoro-gummite**, Texas, 430.
Yttrialite, Texas, 430.
Minerals of Japan, T. Wada, 89, 399.
 — melting points of, Brun, 259.
Mixter, W. G., carbon and its heat of combustion, 434.
Moissan, Canyon Diablo meteorite, 191, 323, 396; artificial diamonds, 451.
Montana, igneous rocks of the Highwood Mts., Pirsson, 330.
Moses, A. J., Elements of Mineralogy, Crystallography, etc., 261.
Mt. Pelée, new studies, Heilprin, 200; eruptions, Lacroix, 465.

N

- Nencki, Marcell**, Opera Omnia, 452.
New Jersey Geol. survey, 88.
North America, submarine valleys off, Spencer, 341.
North Pole, improbability of land at the, Spencer, 333.
"N"-Rays, Blondlot, 455; Broca, 195; Gehrcke, 245.
 — photography, Weiss and Bull, 245.
Nuclei, distribution produced by the X-rays, Barus, 175.

O

OBITUARY.

- Frazier, B. W., 204.
 Medlicott, H. B., 473.
 Packard, A. S., 264.
 Struve, Otto, 473.
 Tacchini, P., 473.
Observatory, Carnegie Institution on Mt. Wilson, Cal., 472; Harvard, 400; publications, Yale, 203; Yerkes, 203.
 Ohio geol. survey, 465.
Optical constants of the eye for different colors, Hastings, 205.
Optics, Theory, Schuster, 250.
Oregon, geology of central, Russell, 458.
Organic Reactions, Lassar-Cohn, translated by J. B. Tingle, 84.
Ostwald, W., Conversations on Chemistry, 324.

P

- Pacific**, Albatross expedition to the eastern, Agassiz, 143, 274, 367.
Palæontologia Universalis, 259.
Panama Canal, problems of, Abbot, 470; project for, Bates, 473.
Parsons, C. L., Elements of Mineralogy, Crystallography, etc., 261.
Payne, J. F., English Medicine in the Anglo-Saxon Times, 263.
Pearce, F., Recherches géologiques et pétrographiques sur l'Oural du Nord, 467.
Penck, A., climatic features in the land surface, 165.
Penfield, S. L., crystal drawing, 39.
Pennsylvania, limestones of southwestern, Clapp, 457.
Percentage Tables, Guttman, 456.
Phosphorescence, Lenard and Klatt, 85.
Physical Science, Recent Development, Whetham, 195.
Physiography and Suess's theories, Davis, 265.
Physiology, Studies in, Loeb, 264, 332.
Pinchot, G., Primer of Forestry, Part II, 471.
Pirsson, L. V., igneous rocks of Highwood Mts., Montana, 330; petrographical notices, 200, 467.
Platinum resources in the United States, 393; in Brazil, 397.
Predazzo, Monzoni, rocks of, Romberg, 201.

Pteraspis dunensis, Drevermann, 464.

Pyrometry, optical, Waidner and Burgess, 329.

R

- Radiation**, polarized Röntgen, Barkla, 391.
 — solar, variation in, Langley, 246.
 — pressure, Bartoli, 86; Poynting, 453.
Radio-active earths, occurrence of, Giesel, 245.
 — measurements, Bronson, 185.
Radio-activity and chemical change, Campbell, 454.
 — of underground air, Dadourian, 16.
Radio-tellurium, Marckwald, 324.
Radium, occurrence of, Giesel, 245.
 — origin, Boltwood, 452.
 — in springs, Colorado, Hadden, 297.
Raymond, P. E., Amphion, Harpina and Platymetopus, 377.
Refractions, double, Braun, 325.

ROCKS.

- Celestite-bearing rocks, Kraus, 286.
 Heptorite, from the Siebengebirge, 201.
 Igneous rocks of Highwood Mts., Montana, Pirsson, 330; Predazzo and Monzoni, Romberg, 201.
 Koswite, 467.
 Peridotite at Ithaca, N. Y., Barnett, 210.
 Rocks of the Andes, Tannhäuser, von Wolff, 201.
 Schists, crystalline, Grubenmann, 202.
 Tilaite, 467.
Rollins, W., Notes on X-light, 86.
Röntgen radiation, polarized, Barkla, 391.
 — see also X-rays.
Ruedemann, R., some primitive cephalopods, 463.
Russell, I. C., geology of central Oregon, 458.

S

- Schaller**, W. T., dumortierite, 211; crystallography of lepidolite, 225.
Schenck, R., Kristallinische Flüssigkeiten, 454.
Schuchert, C., notice of Williams' and Kindle's Devonian Paleontology, 460; paleontological notices, 197, 258, 460.
Schuster, A., Theory of Optics, 250.

Science and Faith, Ideals of, Hand, 268.

Scottish National Antarctic Expedition, 262.

Self-inductance, measurement, Whitehead and Hill, 149.

Smith, J. C., Prost's Manual of Chemical Analysis, 453.

Smithsonian Institution, annual report, Langley, 91, 261.

Smyth, C. H., Jr., replacement of quartz by pyrite, 277.

Soils, field operations of the Bureau of, 1903, Whitney, 471.

Solar radiation, possible variation, Langley, 246.

South Africa, glaciation, Frames, 197.

Spectra of hydrogen, helium, etc., Schniederjost, 85.

— metals in an electric oven, King, 326.

Spectrum Analysis, Watts, 247.

— of carbonic acid, dependence upon pressure, Schaefer, 245.

Spencer, J. W., submarine canyon of the Hudson River, 1; improbability of land at the North Pole, 333; submarine valleys off North America, 341.

Starry Heavens, How to know the, Irving, 204.

Storage cells, new form of electrode, Dadourian, 315.

Sudbury mining district, Barlow, 381.

Sun, see SOLAR.

T

Tables, Percentage, Guttman, 456.

Tantalum, see CHEMISTRY.

Telescope, reflecting, 250.

Temperatures, subterranean, plan for obtaining, Gilbert, 393.

Terrestrial Magnetism, Bauer, 248.

Texas, mineral research in Llano Co., Hidden, 425.

Transvaal, "Cullinan" diamond from, Hatch and Corstorphine, 395.

— oldest sedimentary rocks of, Hatch, 258.

U

United States geol. survey. See GEOL. REPORTS AND SURVEYS.

— platinum resources in, 398.

Urals, geological and petrographical researches in the, Duparc and Pearce, 467.

V

Valleys, submarine, J. W. Spencer, 1, 341.

Van Hise, C. R., Treatise on Metamorphism, 251.

Venezuela, ueber Untersilur in, Drevermann, 197.

Vermont geol. survey, 395.

Viola, C. M., Grundzuge der Kristallographie, 467.

Volatile substances, apparatus for determining, Kreider, 188.

W

Walcott, C. D., Cambrian Brachiopoda, 329.

Ward, H. A., Billings meteorite, 240.

Water, specific heat of, Dieterici, 454.

Watts, W. M., Study of Spectrum Analysis, 249.

Weather forecasts, long-range, Garriott, 263.

Webster, A. G., Dynamics of Particles, etc., 327.

Wells, deep, of 1904, 459.

Whetham, W. C. D., Recent Development of Physical Science, 195.

White, C. H., autophytography, 231.

Whitehead, J. B., measurement of self-inductance, 149.

Williams, H. S., Devonian Paleontology, 460.

X

X-Light, Notes on, Rollins, 86.

X-Rays, production of nuclei by, Barus, 175.

Y

Yale Observatory, publications, 208.

Yerkes Observatory, publications, 208.

Z

ZOOLOGY.

Birds, catalogue of, in British Museum, Ogilvie-Grant, 472.

— of North and Middle America, Ridgway, 332.

Lepidoptera Phalaenæ, Noctuidæ, Hampson, 472.

Orthoptera, synonymic catalogue, British Museum, Kirby, 332.

THE
AMERICAN
JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEORGE L. GOODALE, JOHN TROWBRIDGE,
W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS ADDISON E. VERRILL, HORACE L. WELLS,
L. V. PIRSSON AND H. E. GREGORY, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,

PROFESSOR HENRY S. WILLIAMS, OF ITHACA,

PROFESSOR JOSEPH S. AMES, OF BALTIMORE,

MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES

VOL. XX—[WHOLE NUMBER, CLXX.]

WITH 15 PLATES.

NEW HAVEN, CONNECTICUT.

1905

THE TUTTLE, MOREHOUSE & TAYLOR PRESS.

CONTENTS TO VOLUME XX.

Number 115.

	Page
AET. I.—Iodine Titration Voltameter; by D. A. KREIDER .	1
II.—Handling of Precipitates for Solution and Reprecipitation; by F. A. GOOCH	11
III.—Estimation of Sulphites by Iodine; by R. H. ASHLEY	13
IV.—Revision of the New York Helderbergian Crinoids; by M. TALBOT. (With Plates I-IV)	17
V.—Petrographic Province of Central Montana; by L. V. PISSON	35
VI.— <i>Croomia pauciflora</i> ; by T. HOLM	50
VII.—Relative Proportion of Radium and Uranium in Radio-active Minerals; by E. RUTHERFORD and B. B. BOLTWOOD	55
VIII.—Side Discharge of Electricity; by J. TROWBRIDGE ..	57
IX.—Effect of High Temperatures on the Rate of Decay of the Active Deposit from Radium; by H. L. BRONSON ..	60

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Amounts of Neon and Helium in the Air, W. RAMSAY: Radio-activity of Thorium, O. SACKUR, 65.—Use of Quartz Apparatus for Laboratory Purposes, MYLIUS and MEUSSER: Permeability of Quartz Vessels to Gases, BERTHELOT: Outlines of Inorganic Chemistry, A. GOOCH and C. F. WALKER, 66.—Spectroscopic Analysis of Gas Mixtures, J. E. LILIENFELD: FitzGerald-Lorentz Effect, MORLEY and MILLER, 67.—Normal Element: Influence of Character of Excitation upon Structure of Spectral lines: Radio-active Minerals, R. J. STRUTT: Absence of excited Radio-activity due to temporary Exposure to γ -Rays, 68.—Handbuch der Spectroscopie, H. KAYSER, 69.

Geology and Natural History—United States Geological Survey, 69.—Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains, N. H. DARTON, 70.—Origin of the Channels surrounding Manhattan Island, New York, W. H. HOBBS, 71.—Isomorphism and Thermal Properties of the Feldspars, A. L. DAY and E. T. ALLEN, 72.—Tin Deposits of the Carolinas, J. H. PRATT and D. B. STERRETT: Tubicolous Annelids of the Tribes Sabellides and Serpulides from the Pacific Ocean, K. J. BUSH, 75.—Student's Text-Book of Zoology, A. SEDGWICK: Preliminary Report on the Protozoa of the Fresh Waters of Connecticut, H. W. CONN, 76.—Études sur l'Instinct et les Mœurs des Insects, J.-H. FABRE: Rocky Mountain Goat, M. GRANT: Catalogue of North American Diptera (or two-winged Flies), J. M. ALDRICH: Fauna and Geography of the Maldives and Laccadive Archipelagoes, J. S. GARDINER: American Museum Journal, 77.—Cold Spring Harbor Monographs, 78.

Miscellaneous Scientific Intelligence—Vom Killmandscharo zum Meru, C. UNLIG, 78.—Glacial Studies in the Canadian Rockies and Selkirks, W. H. SCHERZER: Solar Observatory of the Carnegie Institution of Washington, G. E. HALE: United States Naval Observatory: Publications of West Hendon House Observatory, Sunderland, 80.

Number 116.

	Page
ART. X.—Mechanical Equivalent of the Heat Vaporization of Water; by R. H. HOUGH	81
XI.—Phosphorescence of Zinc Sulphide through the Influence of Condensed Gases obtained by Heating Rare-Earth Minerals; by C. BASKERVILLE and L. B. LOCKHART	93
XII.—Action of Radium Emanations on Minerals and Gems; by C. BASKERVILLE and L. B. LOCKHART	95
XIII.—Behavior of Typical Hydrous Bromides when Heated in an Atmosphere of Hydrogen Bromide; by J. L. KREIDER	97
XIV.—Glacial (Dwyka) Conglomerate of South Africa; by E. T. MELLOR	107
XV.—Formation of Natural Bridges; by H. F. CLELAND ..	119
XVI.—Quartz from San Diego County, California; by G. A. WARING	125
XVII.—Radio-active Properties of the Waters of the Springs on the Hot Springs Reservation, Hot Springs, Ark.; by B. B. BOLTWOOD	128
XVIII.—Genesis of Riebeckite Rocks; by G. M. MURGOCI ..	133
XIX.—Purpurite, a new Mineral; by L. C. GRATON and W. T. SCHALLER	146

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Studies with the Liquid Hydrogen and Air Calorimeters. 1. Specific Heats, J. DEWAR, 152.—Thermo-electric Junction as a Means of determining the Lowest Temperatures, J. DEWAR, 153.

Geology—Geology of the Vicinity of Little Falls, Herkimer County, H. P. CUSHING, 156.—Geology of the Watkins and Elmira Quadrangles, accompanied by a geologic map, J. M. CLARKE and D. D. LUTHER, 157.—Geologic map of the Tully Quadrangle, J. M. CLARKE and D. D. LUTHER, 158.—Contribution to the Paleontology of the Martinez Group, C. E. WEAVER: Faune cambrienne du Haut-Alentejo (Portugal), J. F. N. DELGADO, 159.—Paraphorhynchus, a new genus of Kinderhook Brachiopoda, S. WELLER: Sympterura Minveri, n. g. et sp.; a Devonian Ophiurid from Cornwall, F. A. BATHER: Ancestral origin of the North American Unionidæ, or freshwater Mussels, C. A. WHITE, 160.—Thalattosauria, a group of marine reptiles from the Triassic of California, J. C. MERRIAM: Geology of Littleton, New Hampshire, C. H. HITCHCOCK: Vorschule der Geologie, J. WALTHER, 161.—Die Moore der Schweiz mit Berücksichtigung der gesammten Moorfrage, J. FRÜH and C. SCHRÖTER, 162.—Study of Recent Earthquakes, C. DAVISON: Introduction to the Geology of Cape Colony, A. W. ROGERS, 163.—Ice Erosion Theory, a Fallacy, H. L. FAIRCHILD, 164.—Hanging Valleys, I. C. RUSSELL, 165.—Glaciation of the Green Mountains, C. H. HITCHCOCK: Ice or Water, H. H. HOWORTH, 166.

Miscellaneous Scientific Intelligence—United States National Museum, R. RATHBUN: Forestry; Tenth Annual Report of the Chief Fire Warden of Minnesota, C. C. ANDREWS: Les Prix Nobel en 1902: Negritos of Zambales, W. A. REED: Magnetic Survey of Japan reduced to the Epoch 1895.0 and the Sea-level, A. TANAKADATE, 167.—Beiträge zur chemischen Physiologie, F. HOFMEISTER: Du Laboratoire à l'Usine, L. HOULLEVIGUE: Traité Complet de la Fabrication des Bières, G. MOREAU and L. LÉVY, 168.

Number 117.

	Page
ART. XX.—Development of Fenestella ; by E. R. CUMINGS. (With Plates V, VI, and VII).....	169
XXI.—Age of the Monument Creek Formation ; by N. H. DARTON	178
XXII.—Iodometric Determination of Aluminium in Alumin- ium Chloride and Aluminium Sulphate ; by S. E. MOODY	181
XXIII.—Secondary Origin of Certain Granites ; by R. A. DALY	185
XXIV.—Tychite, a New Mineral from Borax Lake, Califor- nia, and on its Artificial Production and its Relations to Northupite ; by S. L. PENFIELD and G. S. JAMIESON	217
XXV.—Modification of Victor Meyer's Apparatus for the Determination of Vapor-Densities ; by B. J. HAR- RINGTON	225
XXVI.—New Lower Tertiary Fauna from Chappaquiddick Island, Martha's Vineyard ; by T. C. BROWN. (With Plate VIII)	229
XXVII.—Production of Radium from Uranium ; by B. B. BOLTWOOD	239

SCIENTIFIC INTELLIGENCE.

Geology—Explorations in Turkestan with an account of The Basin of Eastern Persia and Sistan. Expedition of 1903, under the direction of RAPHAEL PUMPELLE, 245.

Number 118.

	Page
ART. XXVIII.—Ultimate Disintegration Products of the Radio-active Elements ; by B. B. BOLTWOOD	253
XXIX.—Use of the Rotating Cathode for the Estimation of Cadmium taken as the Sulphate ; by C. P. FLORA ..	268
XXX.—Crystallization of Luzonite ; and other Crystallo- graphic Studies ; by A. J. MOSES	277
XXXI.—Determining of the Optical Character of Birefract- ing Minerals ; by F. E. WRIGHT	285
XXXII.—Groups of Efficient Nuclei in Dust-Free Air ; by C. BARUS	297
XXXIII.—Studies in the Cyperaceæ ; by T. HOLM	301
XXXIV.—Preliminary Note on some Overthrust Faults in Central New York ; by P. F. SCHNEIDER	308
XXXV.—Petrography of the Tucson Mountains, Pima Co., Arizona ; by F. N. GUILD. (With Plate IX.)	313

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Gases produced by Actinium, DEBIERNE : New Heavy Solution, DUBOIN, 319.—Hydrolysis of very Concentrated Ferric Sulphate Solutions, RECOURA : Separation of Gold from the Metals of the Platinum Group, JANNASCH and VON MOYER : Determination of Sugar with Fehling's Solution, LAVALLE, 320.—Slow Transformation Products of Radium, E. RUTHERFORD, 321.

Geology and Mineralogy—Indiana, Department of Geology and Natural Resources, Twenty-ninth Annual Report, W. S. BLATCHLEY, 322.—Geological Survey of Louisiana : Geological Survey of New Jersey : Brief descriptions of some recently described Minerals, 323.

Number 119.

	Page
ART. XXXVI.—A New Niobrara Toxochelys; by G. R. WIELAND. (With Plate X.)	325
XXXVII.—Contributions to the Geology of New Hampshire. I. Geology of the Belknap Mountains; by L. V. PIRSSON and H. S. WASHINGTON. (With Plate XI.)	344
XXXVIII.—The Fauna of the Chazy Limestone; by P. E. RAYMOND.	353
XXXIX.—The Mechanical Properties of Catgut Musical Strings; by J. R. BENTON	383
XL.—Use of the Rotating Cathode for the Estimation of Cadmium taken as the Chloride; by C. P. FLORA ...	392

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—Formation of Ozone by Ultra-violet Light, FISCHER and BRAEMER: New Reagent for Nickel, TSCHUGAEFF, 397.—Electrolytic Dissociation Theory with some of its Applications: Soils and Fertilizers: Engineering Chemistry, 398.—Text-book of Chemical Arithmetic: Text-book of Physiological Chemistry for Students of Medicine: Formation of Helium from the Radium Emanation, 399.—Blondlot's "Emission pesante": Diffusion of Nascent Hydrogen through Iron, A. WINKLEMAN, 400.—Landolt-Börnstein Physikalisch-chemische Tabellen, 401.

Geology and Mineralogy.—United States Geological Survey, 402.—Osteology of Baptanodon, C. W. GILMORE, 403.—Cambrian Fauna of India, C. D. WALCOTT, 404.—Catalogue of Type-Specimens of Fossil Invertebrates in the Department of Geology, U. S. National Museum, 405.—Graptolites of New York; Part I, Graptolites of the Lower Beds, R. RUEDEMANN: Mesozoic Plants from Korea, H. YABE: Paleontologia Universalis: Ninth Annual Report of the Geological Commission, Dept. of Agriculture, Cape of Good Hope, for 1904: Rock Cleavage, C. K. LEITH, 406.—Experiments on Schistosity and Slaty Cleavage, G. F. BECKER: Die Alpen im Eiszeitalter, 407.—Structural and Field Geology, J. GEIKIE: Clays and Clay Industry of Connecticut, G. F. LOUGHLIN, 408.—Geology of Western Ore Deposits: Delavan Lobe of the Lake Michigan Glacier, etc., 409.—Platinum in Black Sands from Placer Mines, D. T. DAY: Cassiterite, W. E. HIDDEN, 410.

Miscellaneous Scientific Intelligence.—Harvard College Observatory: Publications of the Cincinnati Observatory: Report of Director of the Yerkes Observatory, Univ. of Chicago: Carnegie Institution of Washington, 411.—Annual Report Board of Regents Smithsonian Institution: Catalogue of Collection of Birds' Eggs in the British Museum of Natural History: Bibliotheca Zoologica II, 412.

Obituary.—Baron FERDINAND VON RICHTHOFEN, Professor LEO ERRERA, Mr. G. B. BUCKTON, M. ELISÉE RECLUS, 412.

Number 120.

	Page
ART. XLI.—Two New Ceratopsia from the Laramie of Converse County, Wyoming; by J. B. HATCHER. (With Plates XII, XIII.)	413
XLII.—Restoration of the Horned Dinosaur Diceratops; by RICHARD S. LULL. (With Plate XIV.)	420
XLIII.—Triassic System in New Mexico; by CHARLES R. KEYES	423
XLIV.—Structure of the Upper Cretaceous Turtles of New Jersey: Agomphus; by G. R. WIELAND	430
XLV.—The Cambro-Ordovician Limestones of the Middle Portion of the Valley of Virginia; by H. D. CAMPBELL	445
XLVI.—Relations of Ions and Nuclei in Dust-free Air; by CARL BARUS	448
XLVII.—Additional Notes upon the Estimation of Cadmium by Means of the Rotating Cathode, and Summary; by CHARLES P. FLORA	454
XLVIII.—The Estimation of Cadmium as the Oxide; by CHARLES P. FLORA	456
XLIX.—The Mounted Skeleton of Triceratops prorsus in the U. S. National Museum; by C. SCHUCHERT. (With Plate XV.)	458

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics.—A New Formation of Diamond, SIR W. CROOKES: A New Compound of Iron, OTTO HAUSER: Nitrosyl Fluoride, RUFF and STÄUBER, 460.—The Atomic Weight of Strontium, T. W. RICHARDS: Qualitative Analysis, E. H. S. BAILEY and H. P. CADY: Charging Effect of Röntgen Rays, KARL HAHN, 461.—Emission of Negative Corpuscles by the Alkali Metals, J. J. THOMSON: A New Method of showing the Presence of Neon, Krypton, and Xenon, S. VALENTINER and R. SCHMIDT: The Mechanical Properties of Catgut Musical Strings, J. R. BENTON, 462.

Geology and Mineralogy.—Iowa Geological Survey, Volume XV, 463.—Summary Report of the Geological Survey Department of Canada, R. BELL: Glaciation of Southwestern New Zealand, E. C. ANDREWS, 464.—Mastodon-Reste aus dem interandinen Hochland von Bolivia, J. F. POMPECKJ: Description of New Rodents and Discussion of the Origin of Daemoneelix, O. A. PETERSON, 465.—Economic Geology of the Bingham Mining District, Utah, 466.—Economic Geology, 467.—Minerals in Rock Sections, L. McI. LUQUER, 468.

Miscellaneous Scientific Intelligence.—National Academy of Sciences, 468.—The Geological Society of America: A Laboratory Guide in Bacteriology, PAUL G. HEINEMANN: British Tunicata, ALDER and HANCOCK, 469.—Catalogus Mammalium tam viventium quam fossilium, E. L. TROUVESSART: Carnegie Institution of Washington: A Handbook of the Trees of California, A. EASTWOOD, 470.

Obituary.—Professor DEWITT BRISTOL BRACE, Professor RALPH COPELAND, Professor D. W. VON BEZOLD, 470.

INDEX TO VOL. XX, 471.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*An Iodine Titration Voltameter*; by D. ALBERT
KREIDER.

THE rapidity, accuracy and sharpness of the end reaction of several of the methods of volumetric analysis, particularly of the iodometric methods, have suggested the possibility of applying them to the voltameter. A rather extensive investigation of quantitative electrolytic oxidation and reduction methods, with this aim in view, has resulted in the evolution of a titration voltameter the accuracy of which may be depended upon to about one part in ten thousand. The advantages in point of manipulation and time required, as well as its applicability to a greater range of current density, will, in the writer's opinion, make it of service in many investigations.

The basis of the method is the electrolysis of potassium iodide and the titration of the liberated iodine by sodium thiosulphate. Herroun* first suggested the use of iodine in this connection. He electrolyzed zinc iodide between a platinum anode and zinc cathode in a beaker; but gives the results of only one determination and leaves the method in an impracticable form.

Danneel† reports four comparative tests of Herroun's zinc iodide voltameter in series with a silver voltameter. The results show a difference of between +0.27 per cent and -1 per cent. His burette readings were made to only the nearest 0.1^{cc}, and the total quantity of thiosulphate was small; varying from 7 to 34^{cc}.

The work of Danneel, as well as that of Kistiakowsky‡ on a silver titration voltameter, seems never to have found its way

* Phil. Mag. [5], xl, 91, 1895.

† Zeitschr. für Elect. Chem., iv, 154, 1897.

‡ Zeitschr. Phys. Chem., vi, 97, 1890.

into the general literature. The work of both men, on voltameters, was incidental to another research and the titles of their articles fail to afford any clue to this particular contents. My own preliminary search of possible reactions had been completed and I had settled upon the form of the iodide voltameter before I learned of the work just mentioned.

Herroun rather erroneously points to the high electrochemical equivalent of iodine as its chief advantage; this is obviously immaterial in a volumetric method. As a basis of a titration method, however, iodine has peculiar advantages in the rapid action of sodium thiosulphate upon it and in the extreme sharpness of the end reactions, intensified when desirable by the addition of starch solution. Potassium iodide is, moreover, much to be preferred to the zinc salt. It is obtainable commercially quite free from iodates and its solutions may, therefore, be acidified without the liberation of iodine, except for the very slow action of atmospheric, or dissolved, oxygen.

It is, of course, impracticable to electrolyze the potassium iodide directly, when the liberated iodine is to afford a measure of the current; this is because of the recombination of the electrode products by diffusion. Acidifying prevents this recombination, or even after it has taken place, in an acid solution the original amount of iodine is liberated, providing the iodine has not been allowed to diffuse to the cathode during the electrolysis, where it would tend to combine with hydrogen and would be irrecoverable.

A most satisfactory action is obtained when the anode is submerged in a strong aqueous solution of the potassium iodide under dilute hydrochloric acid in which the cathode is suspended. With the electrodes thus placed vertically, the anode below, the liberated iodine, because of its great density and solubility in potassium iodide, diffuses very slowly. After a run of hours, and even on subsequent standing for hours more, the solution about the cathode remains perfectly colorless and free of iodine.

The Potassium Iodide Cell.

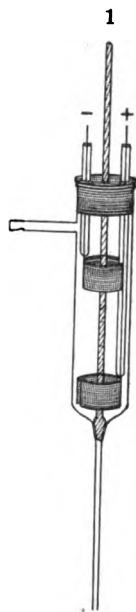
As a cell, I have employed a side-necked test tube, fig. 1, drawn out at the bottom to a long capillary. Into the junction of this capillary a glass rod was ground. The test tube was closed by a rubber stopper with three perforations, through the middle one of which the ground glass rod passes air tight, though not so tightly as to prevent easy motion when moist. The other perforations receive the glass tubes through which the wires connect with the platinum electrodes; anode at the

bottom of the tube, cathode above. The size of the electrodes was, in the small cell, $1.6 \times 2.7\text{cm}$; in the large cell, $2.5 \times 6\text{cm}$. In the latter case the cathode was somewhat smaller and corrugated. These electrodes were bent into cylindrical form and arranged coaxially with the tube. The smaller cell had a diameter of 2cm , length, 12cm , length of capillary, 7cm . Its capacity was about 30cc ; about 7cc being required to cover the anode. The larger cell was made in the same way, of a tube 3cm in diameter and about 15cm in length, with a capillary about 18cm long. With the distance of 5cm between the nearest edges of the electrodes, the total volume required to cover the cathode was about 60cc , about 20cc sufficing to cover the anode.

The apparatus was filled by raising the ground glass rod and by diminished pressure, effected through the side neck, drawing up through the capillary successively the required amount of hydrochloric acid and then the strong solution of potassium iodide in water. In this way the anode is completely submerged in the concentrated solution of iodide without the use of excessive quantities. The hydrochloric acid serves as an electrolyte, permitting the separation of the electrodes sufficiently to preclude the possibility of any interaction of the electrode products.

By this method of filling the cell the iodide is sufficiently acidified, and if not too rapidly drawn in, a sharp line will mark the junction of the two solutions of different density. The electrolysis results in a quantitative liberation of iodine unless the current density is too great. In the latter case oxygen is evolved along with the iodine. With the permissible current densities indicated in Table I, so long as the potassium iodide is not impoverished about the anode, not a trace of oxygen appears and the action is entirely satisfactory. As the iodine is liberated it sinks along the electrode and by its convection effect renews the iodide at the surface of the electrode without the slightest disturbance of the supernatant acid. In all cases where the current density has not exceeded the indicated maximum, or where the duration of the current has not been such as to exhaust the iodide (so that no oxygen is evolved) the supernatant liquid remains perfectly colorless and free of iodine, and continues to show a sharp line of demarcation between the iodine solution and the acid.

Table I shows the possible current densities, potential change, and permissible time of run, under the given conditions. In the first column, the first figure represents the num-



ber of grams of potassium iodide used and the second figure the volume of its solution in water. In the fifth column, where two figures are given, the first represents the fall of potential through the cell at the beginning of the experiment and the second figure that at the end of the run. The interval is found in the sixth column. An asterisk following the figures of the sixth column indicates that the current was continued until, and stopped at the moment of, the first appearance of gas on the anode. It is evident that the liberation of iodine is no longer quantitative for some time before this gas appears, the safety limit depending upon the current density. Within this safety limit the rise of potential is also not as great as that indicated in the fifth column. The fall of potential through the cell increases continuously and very regularly, after the first few minutes, in which it rises rather more rapidly. Just before the appearance of the gas the potential naturally rises quite rapidly. The gradual change of potential is doubtless due to the increased resistance of the potassium chloride solution which is formed during the electrolysis at the boundary of the two solutions. This part of the cell, especially the small one, is always considerably heated by the current, and a conspicuous line of increased density of the solution, but entirely colorless, gradually creeps up the tube to a distance of several centimeters in an hour's run. In the 7th experiment the solution became quite warm and small bubbles of gas appeared on the sides of the glass, long before there was any evidence of gas being evolved at the anode. To test the correctness of the supposition that this was merely dissolved gas, the 8th experiment was made with the cell in a water bath maintained at 9°. Under these conditions no gas appeared until it was evolved at the anode. This experiment also shows that the warming of the solution is, if anything, an advantage; due, doubtless, to the more rapid diffusion of the iodide or to the greater solubility of the iodine. In experiments 3 and 10 the current was varied; the time of run for each value of the current is given in the sixth column.

Three determinations with two of the small cells in series, each containing 2 grams of potassium iodide in 7.5 cc, with a current density of 0.015 amp./cm² showed the following satisfactory agreement in the amount of thiosulphate required:

(a)	$\begin{cases} 31.55^{\circ\circ} \\ 31.58^{\circ\circ} \end{cases}$	(b)	$\begin{cases} 28.60^{\circ\circ} \\ 28.66^{\circ\circ} \end{cases}$	(c)	$\begin{cases} 16.62^{\circ\circ} \\ 16.60^{\circ\circ} \end{cases}$
-----	--	-----	--	-----	--

A comparison between the values obtained by two of the iodine voltameters in series with each other and with one or more copper voltameters is shown in Table II. The titrations

in these cases were not as accurately made, nor the solutions standardized with the same care that characterized the later determinations, as will be seen from the sequel.

TABLE I.

(a) Small cell { Diam. of cell = 2^{cm}.
Length of cell = 12^{cm}.
Electrodes 1.6 × 2.7^{cm}.
Dist. between nearest edges of electrodes, 5^{cm}.

KI grms. in cc. of solution	HCl (1:4) cc.	Current (approx.) amp.	Current density (approx.) amp./cm ²	P. D. Volts.	Time of run, mins.	
1 1 in 5	not measured	0.13	0.015	2.25	22*	
2 2 " 5		0.13	0.015	2.00	35*	
3 2 " 7.5	"	0.25	0.029		15	
		0.40	0.046		2 more	
		0.5	0.058		4½ more*	
4 2 " 7.5	"	0.5	0.058	7.1 to	7.8 15*	
5 2 " 7.5	20	0.5	0.058	3. "	4.7 13*	Solid iodine at anode Solid iodine at anode Solution alkaline Solid iodine in large quantity at anode
6 4 " 7.5	5	0.5	0.058	5. "	12.5 47*	
7 5 " 7.5	20	0.5	0.058	2.4 "	4.8 85*	
8 5 " 7.5	20	0.5	0.058	2.6 "	5.8 54*	
(b) Large cell { Diam. of cell = 3 ^{cm} . Length of cell = 15 ^{cm} . Electrode (anode) 2.5 × 6 ^{cm} . Distance nearest edges, 5 ^{cm} .						
9 5 " 20	40	0.5	0.017	2. "	3.5 41*	Solid iodine at anode
		0.5	0.017	1.5 "	2.5 91	
10 10 " 20	40	1.0	0.033	4.1 "	4.7 2 more	
		1.5	0.050	5.7	1 more*	Solid iodine at anode

* Gas evolved at anode.

TABLE II.

Iodine voltmeter.						Cu-voltmeter.		
Distance between elec- trodes, cm.	KI grms. in cc.	Cur- rent amp.	Amp./cm ²	Time, mins.	Na ₂ S ₂ O ₃ cc.	Copper equiv- alent, grms.	Copper grms.	Amp./cm ²
1 { (a) (b)	5.4 in 7.5	0.5	0.058	25	73.90	0.2391	0.2379	0.013
	1.4 " 7.5				73.72	0.2385		
2 { (a) (b)	5.4 " 7.5	0.5	0.058	45	132.87	0.4202	0.4199	0.013
	5.4 " 7.5				132.71	0.4198	0.4203	
3	5.5 " 7.5	0.5	0.058	45	134.21	0.4244	0.4234 0.4240	0.013

Standard Solutions.

Sodium thiosulphate is the most convenient medium for the titration of iodine, but it is not a very satisfactory standard where great accuracy is desired. The salt is readily obtained quite pure, but there is always some uncertainty as to the amount of extraneous water the crystals may contain. Further, on long standing, especially when exposed to the light, it undergoes a slight decomposition, with deposition of sulphur. However, this decomposition is so slow that, if kept in the dark, the solution will remain quite constant for months. In all of my titrations, except those that were merely relative, I have employed an approximately decinormal solution of sodium thiosulphate, standardized against arsenious oxide, by means of an iodine solution. The purest arsenious oxide obtainable was resublimed three times and weighed from a weighing bottle. This solution also was only approximately decinormal. The weight of the arsenious oxide was carefully determined and reduced to its weight in vacuo, and the solution accurately made up to one liter at 20° in a calibrated flask. The direct employment of the arsenic solution for the titrations is undesirable because it necessitates an excess of bicarbonate and the danger of loss of iodine in the neutralization requires a complicated series of traps. Moreover, the end reaction, when starch is employed, is much slower with arsenic than with the thiosulphate. With the latter it is practically instantaneous.

The Titrations.

The titrations were performed in Ehrlenmeyer beakers. In filling the cell, care was always taken to draw up the last of the iodide solution as far as the ground glass joint, but without admitting air which would stir up the solutions. To avoid a possible loss of iodine through a considerable leakage of the joint and vaporization from the concentrated solution, the Ehrlenmeyer beaker containing about 150^{cc} of water was placed under the cell during the electrolysis. The capillary extension of the cell (fig. 1) reached to the bottom of the beaker. Whenever the leakage of the ground glass joint was sufficient to allow the iodine solution to descend the full length of the capillary during an experiment, the joint was reground with the finest emery. Under these conditions a loss of iodine is impossible.

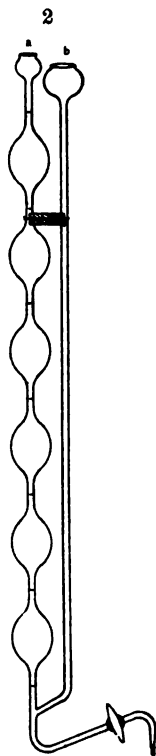
After the current was cut off, the ground glass joint was opened slightly and the cell allowed to empty slowly. The great density of the iodine solution keeps it continuously covered with a layer of water of considerable depth in the

beaker, and the supernatant acid of the cell washed out the iodine completely.

A burette of 50^{cc} capacity was employed. This burette was carefully calibrated and was found to be surprisingly accurate. Its error indicates an extremely minute and regular taper of the tube and the graduations are such as to permit of accurate readings to 0.02^{cc}. In fact I have felt considerable confidence in reading it to 0.01^{cc}. This, with the strength of solution employed, was equivalent to about 0.1^{mg} of silver. In the earlier determinations, when more than 50^{cc} of the thiosulphate were required, the burette was in some cases refilled, which, of course, multiplied the error of reading. In other cases, where the amount of thiosulphate was approximately known, a sufficient quantity was added to the beakers from calibrated pipettes of various size, so that the additional amount required should be less than 50^{cc}. This is, of course, less exact and impractical as well, unless the amount required is approximately known.

In the later determinations a bulb burette, fig. 2, was employed. This contained 6 bulbs, each of approximately 25^{cc} capacity, connected by small tubes of about 2 to 3^{mm} internal diameter. At about the middle of these tubes marks were etched in such a way as to permit readings without error of parallax. The smallness of the tubes prevented filling the burette from the top and to avoid the uncertainty of rubber connections a small side tube, also about 2 to 3^{mm}, terminating in a funnel, *b*, was sealed on and supported by a section of cork as shown. A finger placed on *a* as the liquid is poured into *b* regulates the flow, so that air bubbles are not carried along and the burette is filled quietly and accurately. Inclining the discharge tube, as shown, is of great advantage in preventing any of the grease from the cock soiling the interior of the burette, a very troublesome feature of the usual burette.

The readings of this burette are naturally extremely accurate. It was employed in bleaching the larger part of the iodine. Experience enabled me to judge from the color about when the remaining iodine was less than that bleached by the contents of one bulb. If there was any difficulty in judging this, a comparison beaker of iodine solution could be employed. At any rate the 50^{cc} burette, with which the titration was com-



pleted, was equal to two of the bulbs, and no difficulty was experienced in keeping within that limit. In case of accidentally overstepping the amount of thiosulphate required, a measured volume of iodine solution may be added and the titration be repeated, subsequent deduction being made for the amount of thiosulphate necessary to bleach the added iodine.

The end reaction was in all cases taken as the bleaching of the iodine color, without starch. This in itself is quite delicate, and I have invariably been able to read it to a small fraction of a drop, when the beaker stood on white paper in a good indirect light. As a confirmation of the reading, 5^{cc} of starch solution was then added and produced a faint purple color. The delicacy of this end reaction was more thoroughly appreciated when, after a number of titrations had been made successively, as in the experiments of Table III, the addition of the starch produced almost precisely the same shade of color in all, despite the fact that a very small fraction of a drop of the thiosulphate produced a distinctly perceptible change in the color.

TABLE III.

	Electrodes, cm.	Dis. bet. electrodes, cm.	KI grms. in cc.	Amperes (approx.)	Amp./cm. (approx.)	Na ₂ S ₂ O ₃ cc.	Difference.	
							cc.	%
(1)	1.6 × 2.7	2	5 in 7.5	0.5	0.058	130.84	0.17	0.13
	1.6 × 2.7	5	5 " 7.5			130.67		
(2)	1.6 × 2.7	2	5 " 7.5	0.5	0.058	128.49	0.06	0.047
	1.6 × 2.7	5	5 " 8.5			128.55		
(3)	1.6 × 2.7	2	5 " 7.5	0.5	0.058	127.36	0.10	0.078
	2.5 × 6.0	5	10 " 20		0.017	127.46		
(4)	1.6 × 2.7	2	5 " 7.5	0.5	0.058	170.67	0.23	0.135
	1.6 × 2.7	5	5 " 7.5			170.67		
	2.5 × 6.0	5	10 " 20		0.017	170.90		

Table III is a record of a number of determinations of the constancy of this voltameter. Two or more of the cells were connected in series, and the conditions in each varied as shown. The time of run for 1 to 3 inclusive was about 45 mins., for the 4th, one hour. The amount of hydrochloric acid (1 : 4) was not measured. Enough of the acid was drawn in to insure the covering of the cathode when the iodide solution was drawn in, and to keep the solution acid throughout the experi-

ment. The iodide was roughly weighed. No correction was made for the blank determinations, nor was special care taken to maintain exact constancy of temperature.

Table IV shows the results of the only two determinations that were made by three of the iodine voltameters in series with each other and with one normal silver gravimetric voltameter. The original readings of the burettes for the required thiosulphate is given in the 6th column. In the 7th column is given the value corrected for the blank determinations. A number of blank determinations for the small cell, when 5 grams of iodide were used, gave, with the blank shown in (2), an average value of 0.07^{cc} of thiosulphate, which is the correction applied to all of the small cells. The large cell, with 10 grams of potassium iodide, showed an average value for a blank determination of 0.21^{cc} of thiosulphate. This is three times instead of twice the value of the small cell, as would be expected were the result due to traces of iodate in the iodide. The uncertainty as to the amount of iodine liberated by iodate, or by dissolved oxygen, or by possible oxidizing impurities of the acid, make it rather more desirable to employ known weights of the iodide and known volumes of the acid and then to correct for the blank determination, than the alternative of securing absolute freedom from these extra sources of liberation of iodine.

In the silver voltameter employed, the cathode was a platinum bowl about 8^{cm} in diameter and 3.5^{cm} in depth. The anode was a silver disc, 5.8^{cm} in diameter, 0.8^{mm} thick, and supported by three platinum wires bent over its edges. This was wrapped in filter paper. The solution was made up of 20 grams of pure silver nitrate, dissolved in 106^{cc} of distilled water. The deposited silver was washed with water and allowed to stand under water over-night. Then washed again with water, finally with absolute alcohol and heated for 4 hrs. in an oven at 160°. Then allowed to cool for an hour in a desiccator before weighing.

TABLE IV.

	Electrodes, cm.	Distance between Electrodes, cm.	KI grms. in cc.	Amp. (approx.)	Amp./cm ² (approx.)	Na ₂ S ₂ O ₃ cc.	Na ₂ S ₂ O ₃ corrected for blank, cc.	Silver equivalent, grms.	Silver (in vac.) ag- voltameter, grms.	Difference.	
										Grms. of silver.	%
1	1.6 × 2.7	2	5 in 7.5	0.5	0.058	152.07	152.00	1.63386	1.63236	0.00150	0.092
	1.6 × 2.7	5	5 " 8.5		0.058	152.06	151.99	1.63375		0.00139	0.085
	2.5 × 6.0	5	10 " 20		0.017	152.19	151.98	1.63364		0.00128	0.078
2	1.6 × 2.7	2	5 " 7.5	0.5	0.00	0.06			1.67934		
	1.6 × 2.7	5	5 " 7.5		0.058	156.40	156.33	1.68042		0.00106	0.063
	2.5 × 6.0	5	10 " 20		0.017	156.55	156.34	1.68053		0.00119	0.071

The titrations in the experiments recorded in this table were made with due regard to all possible sources of error. The solutions were brought precisely to the temperature of 20° , at which temperature the room was maintained. The burettes had been thoroughly cleaned with chromate solution, and of course, ample time was allowed for the burettes to drain to a constant reading. The results show that the iodine voltameter, even after the correction for the blank determinations, run uniformly higher by from 0.06 per cent to .09 per cent; but that they agree among themselves to an order of accuracy of about 1 part in 10,000.

Sloane Physical Laboratory,
Yale University, June 5, 1905.

ART. II.—*The Handling of Precipitates for Solution and Reprecipitation*; by F. A. GOOCH.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxv.]

IN many processes of analytical chemistry, the preparation of substances in pure condition is brought about by precipitation, solution, and reprecipitation; and sometimes this cycle of operations must be repeated. When a precipitate, gathered upon a filter, is easily acted upon by the appropriate solvent, the process of dissolving the precipitate from the filter is simple; but when the precipitate is refractory toward solvents or difficult to attack on account of its physical condition, as is the case with many gelatinous precipitates, the proper handling of the precipitate involves some inconvenience and delay.

In meeting such difficulties, I have found it advantageous to place within the ordinary paper filter, before filtering, a movable lining of platinum gauze upon which the precipitate rests for the most part and with which it may be removed. The simplest form of this device is easily made by cutting platinum gauze to the shape shown in the accompanying figure. In ordinary use, this piece of gauze, folded to make a cone of angle a little less than 60° , and held by pincers at the point of overlapping, is placed within this filter and allowed to fit itself closely by the natural spring of the gauze when released.

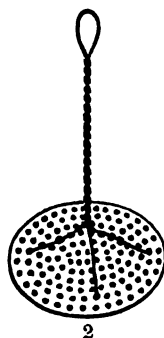


Upon filters so prepared a precipitate may be collected and washed as usual; and, at the end of the operation, the cone with nearly all the precipitate may be transferred, by means of ivory-pointed pincers, to dish or beaker for suitable treatment. The small amounts of the precipitate which have passed through the gauze, being somewhat protected by the gauze against the compacting action of filtration and washing, are generally removable with ease from the filter by a jet of the washing-liquid. After washing, the gauze may be replaced within the same filter and serve for a second collection of the precipitate to be subsequently dissolved, in case double precipitation and solution are desirable. The final collection of the precipitate is, of course, made upon paper without the gauze lining, when precipitate and filter are to be ignited.

This device has proved very serviceable in the handling of such precipitates as ferric hydroxide, aluminium hydroxide, and basic acetate precipitations.

12 Gooch—*Precipitates for Solution and Reprecipitation.*

I have used also in the manipulation of such precipitates a regularly made cone of 60°, fitted with eyelets for handling; but the simple folded cone is, on the whole, more convenient.



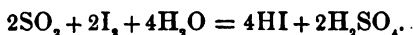
Precipitates collected upon asbestos in the perforated crucible are frequently removable without difficulty by allowing a suitable solvent to percolate precipitate and felt; but in case the precipitate is pasty or compacted, solution in this manner may be unpleasantly slow. In such cases, it is convenient to remove the greater part of the precipitate, collected and washed in the usual manner, upon a disc of platinum foil, perforated, fitted with a wire handle, as shown in the figure and placed upon the asbestos felt before the transfer of the precipitate to the crucible. To make such a disc, shown in figure 2, is the work of a few moments only; and by its use pasty precipitates, such as cuprous sulphocyanide or the sulphides of the metals, are easily handled for solution.

These simple devices so facilitate the manipulation of precipitates in many processes of analysis that they have seemed to be worthy of description.

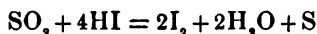
ART. III.—*The Estimation of Sulphites by Iodine*; by
R. HARMAN ASHLEY.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxvi.]

VOLHARD's method for the determination of sulphur dioxide and sulphites is accurate and reliable, but involves the inconvenience of making up every solution to be examined accurately to a standard volume of which portions are to be drawn from a burette and made to react with definite amounts of a standardized solution of iodine. The method consists in running the unknown sulphite or sulphurous acid solution into a known amount of a standardized solution of iodine, acidified with hydrochloric acid, to the disappearance of the iodine reaction with starch. This procedure rests upon the facts that the oxidation of sulphite is brought about in the acidified solution and that, as Bunsen showed, no more than a small proportion of hydriodic acid should be present at the point at which the bodies are made to react. The reaction for the oxidation of sulphur dioxide proceeds normally in dilute solutions according to the equation



In solutions too concentrated, however, the secondary reaction



takes place as Volhard has shown*, and vitiates the indications.

To avoid the inconvenience of the Volhard method it has been proposed by Rupp† to bring about the oxidation of sulphites by treatment with an excess of standardized iodine in a solution made alkaline by acid sodium carbonate, and then, after fifteen minutes, to titrate the excess of iodine by sodium thiosulphate. This procedure, however, is, as has been shown by Ruff and Jaroch‡ and by the present writer,§ faulty in principle and practice, and gives correct results only by a chance balancing of opposing errors. Theoretically it might be possible to overcome the difficulties by treating with acid the alkaline mixture of iodine and sulphite and acid sodium carbonate

* Ann. Chem. 242, 98.

† Ber. Dtsch. Chem. Ges. xxxv, 3694.

‡ Ber. Dtsch. Chem. Ges. xxxviii, 409.

§ This Journal, vol. xiv, p. 237.

before attempting to titrate by sodium thiosulphate the excess of iodine.

In the experiments recorded in the table the following procedure was followed: the sulphite was treated with 1 gram. of acid sodium carbonate and an excess of standardized iodine solution. The solution was then acidulated with a safe amount of hydrochloric acid, it having been found by experiment that the presence of 10^{cm}³ of 1 : 4 hydrochloric acid in 125^{cm}³ of water was without effect upon the determination of iodine by sodium thiosulphate. The excess of iodine after acidification was titrated by standardized sodium thiosulphate. It will be noticed that in the experiments recorded under A of the table, the excess of iodine used was small and in these experiments large negative errors are obtained; while in the experiments recorded under B, in which a large excess of iodine was employed, the results are better. They are best when at least twice as much iodine is added as is theoretically required to oxidize the sulphur dioxide. The length of time during which the iodine may act does not affect the results to any very marked degree.

Iodine value of SO ₂ taken. gram.	Iodine taken. gram.	Iodine value of Na ₂ S ₂ O ₃ used. gram.	Error.		Excess of HCl 1 : 4. cm ³ .	Vol. at titra- tion. cm ³ .
			In terms of Iodine. gram.	In terms of SO ₂ . gram.		
0·2197	0·3143	0·0978	—0·0032	—0·0008	7·5	125
"	"	0·0965	—0·0019	—0·0005	"	"
"	"	0·0970	—0·0024	—0·0006	"	"
0·1535	0·1913	0·0464	—0·0086	—0·0022	"	"
"	"	0·0467	—0·0089	—0·0022	"	"
"	"	0·0472	—0·0094	—0·0024	"	"
"	"	0·0465	—0·0087	—0·0022	"	"
0·2366	0·3194	0·0903	—0·0075	—0·0019	"	"
0·2906	0·3825	0·1132	—0·0213	—0·0054	"	"
0·3825	0·4463	0·0750	—0·0112	—0·0028	"	"

B						
0·1143	0·3143	0·1990	+0·0010	+0·0003	5·0	125
"	"	0·1982	+0·0018	+0·0004	"	"
"	"	0·1992	+0·0008	+0·0002	"	"
"	"	0·1986	+0·0014	+0·0003	"	"
0·1482	0·3187	0·1708	—0·0003	—0·0001	7·5	"
0·1576	0·3187	0·1586	+0·0025	+0·0006	"	"
"	"	0·1643	—0·0032	—0·0008	"	"
"	"	0·1598	+0·0013	+0·0003	"	"
"	"	0·1606	+0·0005	+0·0001	"	"
"	"	0·1602	+0·0009	+0·0002	"	"

(B)

Iodine value of SO ₂ taken. gram.	Iodine taken. gram.	Iodine value of Na ₂ S ₂ O ₃ used. gram.	Error.		Excess of HCl 1 : 4 cm ³ .	Vol at titra- tion. cm ³ .
			In terms of Iodine. gram.	In terms of SO ₂ . gram.		
0.1576	0.3187	0.1622	-0.0011	-0.0003	7.5	125
0.1560	0.3195	0.1660	-0.0025	-0.0006	"	"
0.1992	0.4460	0.2482	-0.0014	-0.0003	"	"
0.1915	0.3825	0.1919	+0.0009	-0.0002	"	"
0.2056	0.3771	0.1701	+0.0014	+0.0003	"	"
"	"	0.1697	+0.0018	+0.0004	"	"
"	"	0.1707	+0.0008	+0.0002	"	"
"	"	0.1709	+0.0006	+0.0002	"	"
[0.2131	0.4470	0.2412	-0.0073	-0.0018]	"	"
0.2354	0.3825	0.1490	-0.0019	-0.0005	"	"
0.2597	0.4463	0.1869	-0.0003	-0.0001	"	"
0.2638	0.4463	0.1847	-0.0022	-0.0005	"	"
0.2908	0.6375	0.3505	-0.0038	-0.0009	"	"
0.3187	0.4463	0.1326	+0.0050	+0.0012	"	"
0.3395	0.6275	0.2842	+0.0038	+0.0009	"	"
"	"	0.2852	+0.0028	+0.0007	"	"
"	"	0.2844	+0.0036	+0.0009	"	"
"	"	0.2855	+0.0025	+0.0006	"	"

Ruff and Jaroch* take the ground that in the favorable results occasionally obtained by Rupp's process, an error due to the over-oxidation of the tetrathionate normally formed in the action of sodium thiosulphate upon the residual iodine is apparently balanced by some oxidation of sulphur dioxide by dissolved air, the iodine in solution acting catalytically as well as directly. The theory, however, is quite at variance with the evidence supplied in the table: for, if it were true, under no conditions could iodine in the presence of air act as a correct measure of sulphur dioxide, as it apparently does when used in a sufficiently large excess; nor does the theory of the catalytic action of iodine explain the fact that when a greater mass of iodine is used, under conditions otherwise similar, we get a larger oxidation of sulphur dioxide.

The most obvious explanation is that at a low concentration of iodine an intermediate oxidation product may be formed and that the formation of this product may be prevented by sufficient concentration of the iodine. It is not unreasonable to suppose that the formation of a small amount of dithionate instead of sulphate is the occasion of the deficient expenditure of iodine noted when the concentration of this element is low, and that the dithionate is not formed appreciably when the

* Loc. cit.

iodine concentration is high. The dithionate once formed is but slowly attacked by iodine, and that is apparently the reason why long standing of the mixtures containing a small proportion of iodine does not result in complete oxidation of the sulphite to sulphate. From these considerations it will be seen that the secondary error of Rupp's process may very probably be due to the formation of some dithionate from the sulphite where the concentration of the iodine is low.

The practical estimation of sulphurous acid or a soluble sulphite may, then, be accomplished with a reasonable degree of accuracy by adding to the solution of the substance, not exceeding 100^{cm}³ in volume and containing a gram of acid sodium carbonate, at least twice as much iodine as is theoretically necessary to effect oxidation, acidifying cautiously with hydrochloric acid, and determining with standard sodium thiosulphate the excess of iodine remaining in the acidified solution.

The author takes this occasion to thank Prof. F. A. Gooch for much kind assistance.

ART. IV. — *Revision of the New York Helderbergian Crinoids*;* by MIGNON TALBOT. (With Plates I–IV.)

THIS paper treats of the Crinoidea of the Helderbergian rocks of New York, and is a continuation of Dr. George H. Girty's thesis, "A Revision of the Sponges and Coelenterates of the Lower Helderberg Group of New York." In Dr. Girty's paper, the term "Lower Helderberg" included the Tentaculite, or Manlius, limestone; but here "Helderbergian," as proposed by Clarke and Schuchert,† is used to include only the Coeymans, or Lower Pentamerus; the New Scotland, or Delthyris Shaly; and the Becraft, or Upper Pentamerus.

With the exception of the work done by Wachsmuth and Springer, who probably used specimens that Hall had studied, the crinoids of the Helderbergian rocks of New York have not received much attention since Hall's descriptions were published, in 1859. Very little subsequent collecting has been done, and for the most part the forms secured have been specimens of *Homocrinus scoparius* and *Edriocrinus poeciliformis* or simply stem fragments, the work of gathering being done in the New Scotland.

A reopening of the old locality at Jerusalem Hill was made, however, in 1901, by Professors Beecher and Schuchert; and a new locality was discovered at North Litchfield, both of these being in the Coeymans limestone. The majority of fossils found were crinoids, but there were also cystids in appreciable numbers and five ophiuroids representing two genera. In the fall of 1903, these collections were increased by more material collected at the same locality by Mr. C. J. Sarle; so that in the Yale University Museum there are now three collections—one from Jerusalem Hill and two from North Litchfield.

The first of these consists mainly of *Homocrinus scoparius*, though it contains uncompressed forms of *Cordylocrinus plumosus* and several good specimens of *Melocrinus pachyductylus*. In the region of Litchfield, the Coeymans limestone attains a thickness of one hundred and fifty feet and *Homo-*

* This paper is part of a thesis presented to the Graduate Faculty of Yale University for the degree of Doctor of Philosophy, in June, 1904. The larger part of the work was done under the supervision of the late Professor Charles Emerson Beecher, for whose help and inspiration the writer wishes to make the most grateful acknowledgment. Type specimens have been studied in the Yale University Museum, the New York State Museum and the American Museum of Natural History; and the thanks of the writer are here expressed to Professor R. P. Whitfield, Dr. J. M. Clarke, Dr. E. O. Hovey and Mr. H. H. Hindshaw, for courtesies in connection with the study, and to Professor Charles Schuchert, who took up the direction of the work after Professor Beecher's death.

† Science, New Series, vol. x, p. 876, 1899.

crinus scoparius is said to range from the Manlius almost to the top of the Coeymans. Most of the specimens in the Yale collection were found about forty-six feet from the top of the section in a twelve-inch layer containing slabs rich in *Homocrinus scoparius* and also specimens of *Melocrinus pachyductylus*, *Anomalocystites cornutus*, *Lepocrinites gebhardi* and the ophiuroids. *Cordylocrinus plumosus* is abundant in the lower bed mentioned later.

The collection from North Litchfield is chiefly from two horizons and is extremely rich. One of these beds is a limestone four inches thick in which are specimens of *Melocrinus nobilissimus* with very large crowns and very stout, long stems and a large form of *Cordylocrinus plumosus* in comparative abundance, the majority of the individuals showing many long cirri crowding around the calyx. The material from this zone has one specimen of *Lepocrinites gebhardi* and several of *Homocrinus scoparius*. Although all the fossils in this bed are of large size, especially is this true of *Melocrinus nobilissimus*, whose columns are very thick and, though only fragments, measure from fifty to seventy centimeters in length. This is long for Paleozoic crinoids. Wachsmuth and Springer state that no columns over three feet in length have been seen from the Paleozoic and that generally they are not over one foot long.* Here there are numbers over two feet in length.

The other horizon, a few inches higher in the section, has furnished slabs covering a floor space of some sixty-five square feet, slabs that are literally covered with crinoid stems and crowns. Here, too, as in the lower bed, are stems over two feet long. The forms represented are *Mariacrinus beecheri*, *Melocrinus nobilissimus*, *M. pachyductylus*, *Thysanocrinus arborescens* and *Cordylocrinus plumosus*. To show the relative abundance of these species, an enumeration of the individuals on the slabs was taken and by actual count there were found, of *Mariacrinus beecheri* thirty-one specimens, of *Melocrinus nobilissimus* six, of *M. pachyductylus* one, of *Thysanocrinus arborescens* ten, and of *Cordylocrinus plumosus* eight hundred and seventy-three, making a total of nine hundred and twenty-one specimens. In addition to these are numerous crinoid columns, several gastropods and brachiopods and one cephalopod. On a small surface of six square feet there are three hundred and twenty crinoids.

The cover of this bed is also in the collection and it is estimated that two-thirds as many more crinoids are on its lower surface. This enumeration was made before anything was done toward developing the slabs and such preparation may

*North American Crinoidea Camerata, vol. i, p. 39; Mem. Mus. Comp. Zool., Harvard College, vol. xx, Cambridge, Mass., May, 1897.

double the number now visible; hence in this one collection, there are undoubtedly more crinoids than in all other collections from New York combined.

The following species, listed by Hall from the Coeymans limestone at North Litchfield, have not been recognized in the Yale material: *Mariacrinus paucidactylus* (probably *Melocrinus pachydactylus*), *M. ramosus*, *M. plumosus*, *Platycrinus parvus* (probably *Cordylocrinus plumosus*), *P. ramulosus* (seems to be restricted to the Cobleskill zone of the Manlius) and *P. tentaculatus*. This is not to be wondered at, however, as a slight change of position, horizontally or vertically, often reveals a different fauna; and as Hall's collections represented gatherings not only from the quarries but also from the stone walls about the town of Litchfield, the fossils undoubtedly came from different horizons and localities.

In the classification, nomenclature and terminology of the crinoids, Wachsmuth and Springer have been followed and the reader is referred to their works, "The North American Crinoidea Camerata"* and "The Revision of the Palæocrinoida."†

Order, INADUNATA Wachsmuth and Springer.

Suborder, FISTULATA, Wachsmuth and Springer.

Family, *Cyathocrinidae* Roemer.

Genus, *Homocrinus* Hall.

Homocrinus scoparius Hall. Plate III, figure 3.

Homocrinus scoparius Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 102, pl. 1, figs. 1-9.—Wachsmuth and Springer, Rev. Palæocr., Pt. I, 1879, p. 79; Proc. Phila. Acad. Nat. Sci., vol. xxxi, 1880, p. 302.—Bather, Kongl. Svenska Vet. Akad., Handl. xxv, 1893, p. 105.

In the collection of crinoids from Jerusalem Hill, N. Y., now in the Yale University Museum, there is a considerable number of slabs showing *Homocrinus scoparius* in abundance. These slabs vary in size from a few centimeters to over half a meter in length and the surfaces are virtually covered with these beautiful fossils. One slab, thirty centimeters long and twenty-three wide, has eighteen specimens, three of which are complete, that is, have the crown and the whole length of the column, including the distal end. Aside from these, there are four other stems and two (possibly three) specimens of *Anomalocystites cornutus* on the same slab. On other slabs from the same horizon are *Melocrinus pachydactylus*, *Anomalocystites cornutus*, *Protaster forbesi*, and *Dalmanites* sp. (?). Many

* Memoirs of the Museum of Comparative Zoology at Harvard College, vols. xx and xxi, with Atlas, Cambridge, Massachusetts, May, 1897.

† Proceedings of the Philadelphia Academy of Natural Sciences, vols. xxxi, xxxiii, xxxvii and xxxviii.

of the specimens of *Homocrinus* are in almost perfect condition, and where the fine cirri are visible on the stem the grace and delicacy of this species are well shown (pl. III, fig. 3).

The following additions are made to Hall's description:—

Ventral sac strong, elongated, sometimes three-fourths as long as the arms, the upper part composed of vertical rows of small hexagonal plates. The upper end of the sac probably has five large plates, which are drawn out into spines, something like those in *Scaphiocrinus unicus*. Three of these spines and traces of a fourth can be seen in one specimen, and their position shows that a fifth was probably present originally. These spines are not scattered irregularly over the upper surface, as is indicated in Hall's figure. Column long and slender, consisting of irregularly alternating larger and smaller joints, round below and becoming obtusely angular and enlarged above. Canal small and round. Shortest column observed 4^{cm} in length; longest, which is still incomplete, 15^{cm} long. Very delicate cirri are preserved, but in no specimen are they found above the middle of the stem. Wherever the distal end of the column is present, there is a coil or loop, as if the stem twined around some support (pl. III, fig. 3). No indications of the clustering of columns mentioned by Hall were seen in the Yale collection.

Horizon and locality.—Common in the thinly laminated or shaly layers of the Coeymans or Lower Pentamerus, at Schoharie, Jerusalem Hill and North Litchfield. Hall reports the species from the Manlius, or Tentaculite, limestone,* but no such specimens have come under the writer's observation.

Cotypes (used by Wachsmuth and Springer for the revised genus) in the American Museum of Natural History, from Litchfield, N. Y.

Family, *Edriocrinidæ* n. fam.

In the specimens of *Edriocrinus* under observation, there are differences that at first seemed to have specific, if not generic value. There are two quite common forms—one (No. 1 and No. 2)† the small hemispherical cups, so well known to collectors in the Helderberg Mountains; and another (No. 3) like the preceding only that the cup has a prominent band or ring around the upper margin. There are other forms that are not so common, however; and they can be divided into two groups, or even three. One specimen (No. 4) about twice as high as the common ones has the hemispherical cup, above which and fused to which is a solid band; and above this still another band of six fused plates, twice as high as the lower

* Nat. Hist. N. Y., Pal., vol. iii, p. 103, 1859.

† Numbers refer to those on pl. IV, figs. 1-6.

band. Another individual (No. 5) does not show the first band, and the second is broken up by weathering into five comparatively broad plates and one narrow one. The next specimen to attract attention (No. 6) resembles the one just described only that on one side the plates succeeding the cup have the appearance of a row of three short plates, instead of one high one.

It was not until these forms, seemingly so different, had been most carefully compared that any conclusion concerning them could be reached. The difficulty was due, mainly, to the fact that in most cases the suture lines are wholly obliterated; but, with a trace of a suture here and another there, there was something on which to base an interpretation. The following solution is offered:

The genus *Agassizocrinus* is said to be dicyclic because young specimens have infrabasals, although the latter are obliterated before maturity is attained. The question has arisen, Why may not the same be true of *Edriocrinus*? By following out this idea, these seemingly distinct forms were reduced to two whose difference is simply in the development of the basals, which in one group are inconspicuous and in the other are enlarged to form the prominent ring or band mentioned above.

The explanation of these varying specimens is as follows: No. 2 and No. 5, instead of being monocyclic, are dicyclic, the infrabasals, which are the largest, being fused with the basals. No. 3 shows infrabasals and basals, the latter being very prominently developed. No. 6 has infrabasals and fractured radials, but no brachials. This conclusion has been reached by comparing opposite sides of the same specimen. Though on one side there seems to be a short radial followed by two short brachials in each ray, the other side shows no such division; and it is evident that the apparent brachials are due to the transverse breaking of the radials. This view is supported by the fact that the anal plate is as high as the radials and the apparent brachials combined. No. 4 shows all the plates of the calyx and furnishes the clue to the others. The prominence of the basals is hardly a specific characteristic and these specimens are all left in the original species, *E. pocilliformis*. In the Yale collection, there is one example of *E. sacculus* which gives faint indications of the presence of infrabasals, though none of the specimens show any thickening of the basal ring.

In regard to classification, these forms certainly cannot belong with the genus *Agassizocrinus* in the family *Astylocrinidae*, where *Edriocrinus* was placed provisionally by Wachs-

muth and Springer,* because there are no supplementary anal plates in the calyx, as is the case in *Agassizocrinus*. Bather lists the genus provisionally under the order *Flexibilia*,† an order with no anal plate in the cup; but, as *Edriocrinus* has such a plate, the genus cannot be so referred. The calyx structure is that of the Cyathocrinidae but there are differences that prevent the reference of *Edriocrinus* to this family. The absence of a column is one of these differences and the manner in which the rays divide is another. In *Cyathocrinus*, which is the most representative genus of the family, the arms in branching spread out irregularly, and the joints are generally higher than wide; while in *Edriocrinus* the joints are very short, and the arms branch as do those of *Ichthyocrinus*, the divisions remaining in contact and curling inward. The arms, however, do not form a part of the calyx as in the last named genus.

Family description.—Calyx elongate. Base dicyclic, probably five fused plates in each order. Radials with facets for the insertion of the brachials extending across the whole width. Arms incurved, seemingly without pinnules, divisions remaining in contact; joints much wider than long. Column wanting, the attachment being by the infrabasals in the young stages; mature forms unattached.

Genus, *Edriocrinus* Hall.

Edriocrinus Hall.

Edriocrinus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 119; 15th Rept. N. Y. St. Cab. Nat. Hist., 1862, p. 115.—Meek and Worthen, Geol. Rept. Ill., vol. iii, 1868, p. 119.—Wachsmuth and Springer, Rev. Palæocr., Pt. I, 1879, p. 21, Pt. III, 1885, p. 10, and 1886, pp. 192, 265, 286; Proc. Phila. Acad. Nat. Sci., vol. xxxi, 1880, p. 244, vol. xxxvii, 1886, p. 232, and vol. xxxviii, 1887, pp. 116, 189, 210; N. Am. Cri. Cam., vol. i, 1897, pp. 59 and 145.—Zittel, Handb. d. Palæontol., I Band, 1880, p. 350.—P. H. Carpenter, Ann. Mag. Nat. Hist., May, 1883, p. 333.—Bather, Rept. Brit. Assoc. Adv. Sci. for 1898, p. 923; A Treatise on Zoology, 1900, Pt. III. The Echinoderma, p. 191.

Amended generic description.—Calyx directly cemented, either throughout life or only in the young stages, the attachment being by the large infrabasals. The cicatrix very large in some specimens and in others obliterated, by the accumulation of calcareous matter on the outer surface of the calyx plates. Infrabasals large, their height being from one-half to two-thirds that of the cup as ordinarily found, completely fused so as to destroy suture lines and to make the number of plates uncertain. Basals five, height varying in proportion to that of

* Rev. Palæocr., Pt. III, p. 192, 1885, or Proc. Phila. Acad. Nat. Sci., vol. xxxviii, p. 116.

† Rept. Brit. Assoc. Adv. Sci. for 1898, p. 923; also The Echinoderma, p. 191, 1900.

the infrabasals, generally so fused as to show no suture lines on the outer surface, although they are often seen on the inner side. Upper margin scalloped for the attachment of the radials and the anal plate. Radials five, large, rectangular, the upper margin excavated slightly for the attachment of the brachials and the lower curved to fit into the concave upper margin of the basals. An anal plate half as wide as the radials and a small plate above it furnish all that is known of the anal area. Ventral surface unknown. Arms known in only one species, *E. sacculus*, where they consist of very short transverse plates and bifurcate several times, but show no trace of pinnules.

Genotype, *E. pocilliformis* Hall.

Edriocrinus pocilliformis Hall. Plate IV, figures 1-6.

Edriocrinus pocilliformis Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 121, pl. v, figs. 8-12.—Meek and Worthen, Geol. Rept. Ill., vol. iii, 1868, p. 370, pl. 7, figs. 5a and 5b.—Wachsmuth and Springer, Rev. Palæocr., Pt. III, 1886, p. 266; Proc. Phila. Acad. Nat. Sci., vol. xxxviii, 1887, p. 190.—Keyes, Geol. Surv. Mo., vol. iv, 1894, p. 221, pl. xxx, fig. 7.

Amended specific description.—Infrabasals present but so fused that their number is uncertain. Height from one-half to two-thirds that of the cup as ordinarily found. Basals five, completely fused with each other and with the infrabasals or distinguished from the latter as a narrow protruding band. Suture lines sometimes apparent on the interior. Upper margin scalloped for the attachment of the radials and the anal plate. Height about half that of the infrabasals. Radials five, often as high as the infrabasals and basals combined, and, like them, fused to form a part of the cup. In most instances, however, the suture lines between the radials are plainly discernible. As a rule, the union between the radials and basals is not so strong as that of basals with infrabasals; and the cup is generally broken off at the top of the basals. Since in no specimens are brachials preserved, the union of brachials with radials must have been still weaker. Anal plate as high as the radials, but only half as wide. Radials and anal gently convex, sloping in all directions from the center of the plate. Arms and ventral disk unknown. The attachment scar is visible on a number of specimens, and in some is a short distance up on the side of the cup, rather than on the bottom.

Horizon and locality.—Throughout the New Scotland limestone in Helderberg Mountains.

Cotypes in the American Museum of Natural History.

Order, CAMERATA Wachsmuth and Springer.

Family, *Thysanocrinidae* Wachsmuth and Springer.

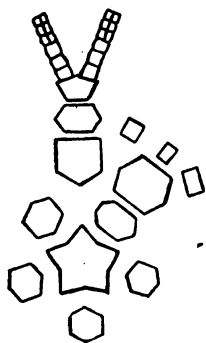
Genus, *Thysanocrinus* Hall.

Thysanocrinus arborescens n. sp. Plate I, figure 2; text-figure 1.

Although, in America, no members of this genus have been reported above the Niagara, a number of crinoids that must

be referred to this genus is found in one of the beds of the Coeymans limestone at North Litchfield. The generic features, as given by Wachsmuth and Springer,* are well marked—the subglobose calyx, urn or bell-shaped; infrabasals five, small, barely protruding beyond the column; basals five, the posterior one truncated by a large anal plate; radials five, considerably larger than the costals; costals two; arms ten or twenty, rather strong and biserial; pinnules long; first interbrachial large, followed by smaller ones; anal side wider, first anal plate followed by three in the next row.

The specimens under examination lack the ridges which are so conspicuous in marking the rays in most of the species of *Thysanocrinus*; their plates are smooth, instead of being sculptured as is generally the case in this genus, and the column is pentangular, while in most of the species it is round. The specimens resemble *T. liliiformis* more closely than any other species, but differ from it in the pentangular column and the absence of the ridges on the radial series of plates. Not enough is known about the bifurcation of the arms in *T. liliiformis* to make comparison.



Text-figure 1.—Diagram of *Thysanocrinus arborescens* showing position of the anal plates and first bifurcation of the arms.

bifurcation occurs, seemingly only on the inner branches and at different intervals in the different arms, varying from the fourteenth to the twenty-third palmar. Pinnules found on the fifth distichal and continuing to the tips of the arms. Column pentagonal. Near the calyx, the joints alternate in size; but farther down the stem every fourth joint is larger. In a specimen in which the crown is 29^{mm} in length, the column, though incomplete, is 40^{cm} long.

* N. Am. Cri. Cam., vol. i, p. 190, 1897.

This species is associated with *Melocrinus nobilissimus*, *M. pachydactylus*, *Mariacrinus beecheri*, and *Cordylocrinus plumosus*.

Horizon and locality.—Upper third of the Coeymans limestone at North Litchfield.

Holotype in the Yale University Museum.

Family, *Melocrinidae* Roemer.

Subfamily, *Melocrininae*.

Genus, *Mariacrinus* Hall.

In re-diagnosing the genera *Mariacrinus* and *Melocrinus*, Wachsmuth and Springer recognized the fact that the arms of the former remain apart and do not form the tubular appendage which is so conspicuous in *Melocrinus*. The only species in the Yale collection that shows this characteristic of *Mariacrinus* is a new species, *M. beecheri*, in which the proximal end of the ray forms a tube while the distal end is divided, the arms diverging conspicuously. The species is thus seen to hold a position intermediate between *Mariacrinus* and *Melocrinus*. As the features of the former are more strongly developed, this species is referred to that genus.

Genotype, *M. plumosus* Hall.

Mariacrinus beecheri n. sp. Plate I, figure 3; text-figure 2.

This species bears a resemblance to *Melocrinus nobilissimus* but differs from it in features other than the division of the rays. The auxiliary arm, instead of being comparatively inconspicuous, as in *Melocrinus*, is strong and prominent and lies alongside the tube.

The joints of the rays are longer than those of *M. nobilissimus*, so that, although the arms are given off more frequently than in the last named species, they seem to take origin at greater intervals. As in *M. nobilissimus*, the stem joints alternate in size, but they are so very thin in all parts of the stem, and especially so near the crown, that there is no difficulty in determining this form by the column alone. The column is also much larger in proportion to the size of the calyx.

Specific description.—Calyx small, elongate, once and a half as long as wide, the increase in width being very gradual. Basals wider than long, pentagonal, not forming a projecting cup, but continuing the width of the column. Radials five, four heptagonal and one hexagonal. Costals two, the first hexagonal, more than half as large as the radials, and the second smaller, pentagonal, and support-



Text-figure 2.—Anal sac of *Melocrinus beecheri* with *a*, *b* and *c* as the last of the anal series of plates in the cup. $\times 44$.

ing two rows of distichals, three in each row. The last distichal supports two rows of palmars, whose first two plates are connected. Above this point, the palmars separate, those on the outside of the ray forming an auxiliary arm which lies alongside the ray but is not connected with it. The inner row of palmars joins corresponding plates from the other row of distichals to form a tubular appendage which extends for a short distance only, when the divisions separate and remain apart to the end of the ray. On the outer side of the ray, arms arise from every fourth or fifth joint; but, on account of the length of the joints, the arms are quite far apart. The arms are biserial to the end. The first interbrachial is large, hexagonal, followed by a double row of alternating hexagonal plates. Anal inter-radius wider and ending in a short thick tube or sac, composed of numerous plates which seem to have been hexagonal originally. This sac is seen in but one specimen, where the plates are very poorly preserved (text-fig. 2). Column circular, with diameter large in proportion to the size of the calyx. Distally the joints alternate in size, but near the calyx they are very thin and of uniform thickness.

Horizon and locality.—Upper third of the Coeymans limestone at North Litchfield.

Cotypes in the Yale University Museum.

Genus, *Melocrinus* Goldfuss.

Genotype, *Mariacrinus nobilissimus* Hall.

Melocrinus nobilissimus (Hall). Plate II.

Mariacrinus nobilissimus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 105, pl. 2, figs. 1-5; pl. 2A, fig. 1.

Melocrinus nobilissimus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. Am. Cri. Cam., vol. i, 1897, p. 295; Atlas, pl. xxiii, figs. 1a, 2 and 3.—Bather, A Treatise on Zoology, 1900, Pt. III. The Echinoderma, p. 161, text-fig. lxxiv, 2.

Sixteen individuals of this species have been added recently to the Yale collections; yet, since the type specimen is so nearly perfect, very little additional knowledge has been gained from this new material. Attention, however, may be called to a few points. One specimen shows a row of three or four small plates between the auxiliary arm and the tubular appendage. These plates appear in the figures given by Wachsmuth and Springer, but no mention is made of them in the descriptions. They seem to be interpalmars, though it is possible that they belong to the ventral disk. The domelike extension of the anal series of plates, which is also figured by Hall, is seen indistinctly in one specimen. One crown has a column attached, over 21^{cm} in length; while another column on the same slab, and to all appearances of the same species, is over 69^{cm} long and gives no indication of proximity to either calyx or distal end.

At North Litchfield, this species was found associated with *Mariacrinus beecheri*, *Melocrinus pachydactylus*, *Cordylocrinus plumosus*, *Thysanocrinus arborescens*, *Homocrinus scoparius*, *Lepocrinites gebhardi*, and *Dalmanites* sp. The crowns are not numerous, but judging from the associated fragments of stems this spot must have been very favorable to the growth of *Melocrinus nobilissimus*. On one slab about fourteen inches long (pl. II), four crowns were found with columns belonging to forty-six more. The only other fossils on this slab are one *Conularia* and two Bryozoan fragments.

Horizon and locality.—Coeymans limestone at Litchfield and North Litchfield.

Cotypes in the American Museum of Natural History.

Melocrinus pachydactylus (Conrad). Plate I, figure 1.

Astrocrinites pachydactylus Conrad, Ann. Rept. Pal. N. Y., 1841, p. 34.—Mather, Geol. Rept. N. Y., 1843, p. 347; text-fig. 6 on p. 345.

Mariacrinus pachydactylus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 107, pl. 3, figs. 1-4.

Mariacrinus paucidactylus Hall, *ibid.*, p. 109, pl. 3, fig. 5.

Melocrinus pachydactylus Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. A. Cri. Cam., vol. i, 1897, p. 296, pl. xxiii, figs. 4 and 5; pl. xxiv, figs. 4a and 4b.

Melocrinus paucidactylus Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 122; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 296; N. A. Cri. Cam., vol. i, 1897, p. 296.

Actinocrinus polydactylus Bonny, Schenectady Reflector, 1835.

Although this species heretofore has been considered a rare fossil, it is now represented in the Yale University Museum by thirteen specimens. Little additional knowledge of the calyx, however, has been gained. In all cases where the distichals can be distinguished from the other plates, their number is two, instead of three. The former number agrees with all previous figures; yet, in their description, Wachsmuth and Springer make the distichals three in number.*

One of the rays, though incomplete, shows nineteen arms, which are plainly seen to be uniserial, not biserial as previously described and figured.† The actinal side of the rays and arms shows the ambulacral groove. As to the number of brachials in the successive orders of the plates of the rays, careful examination of the specimens at Yale yields results different from those reached by Wachsmuth and Springer.‡ Brachials of the fourth, fifth and sixth orders have seven plates, and the subsequent orders seem to alternate with six and seven to the

* N. Am. Cri. Cam., vol. i, p. 296, 1897.

† Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 108, pl. 3, figs. 1-3 and 4a; N. Am. Cri. Cam., Atlas, pl. xxiii, figs. 4 and 5; pl. xxiv, figs. 4a and 4b, 1897.

‡ *Ibid.*, vol. i, p. 297.

end of the ray. In one specimen, small dome-like interpalmars show between the auxiliary arm and the tubular appendage, occupying the same position as in *M. nobilissimus*, but differing in form. Stem joints alternate in size near the calyx, but farther down the column every fourth one is larger. One individual has a stem 19^{cm} long, which makes a loop at the distal end about 2.5^{cm} in diameter. Another loop not more than 1^{cm} in diameter has two complete whorls.

M. pachydactylus is found at Jerusalem Hill with *Lepocrinites gebhardi* and many specimens of *Homocrinus scoparius*; at North Litchfield with *Mariacrinus beecheri*, *Melocrinus nobilissimus*, *Thysanocrinus arborescens*, and *Cordylocrinus plumosus*.

Wachsmuth and Springer regard *M. paucidactylus* and *M. pachydactylus* as synonyms, but give no reasons therefor. Hall's distinctions are the narrower calyx and the fewer and more distant arms of the former. The specimen figured on pl. I, fig. 1, is very narrow, proving the width of the calyx to be variable. The greater distance between the branches of the arms cannot, in itself, be considered a specific difference; and there seems to be no reason for referring these narrow specimens to another species.

Horizon and locality.—Near the base of the Coeymans limestone at Schoharie;* in the upper third of the same limestone at Jerusalem Hill and North Litchfield.

Family, *Platycrinidæ*.

Genus, *Cordylocrinus* Angelin.

Cordylocrinus plumosus (Hall). Plate III, figures 2 and 4; text-figure 3.

Platycrinus plumosus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, pp. 113 and 148, pl. 4, figs. 1-5.

Platycrinus parvus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 114, pl. 4, figs. 6-9.

Cordylocrinus plumosus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 61; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 235; N. Am. Cri. Cam., vol. ii, 1897, p. 737; Atlas, pl. lxxv, fig. 20.

Cordylocrinus parvus Wachsmuth and Springer, Rev. Palaeocr., Pt. II, 1881, p. 60; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 234; N. Am. Cri. Cam., vol. ii, 1897, p. 737.

Clematocrinus plumosus Jaekel, Zeit. d. deutsch. Geol. Gesell., Band xlix, 1897, Verhandl., p. 47.

Clematocrinus parvus Jaekel, Zeit. d. deutsch. Geol. Gesell., Band xlix, 1897, Verhandl., p. 737.

In the Yale Museum, there are many hundreds of specimens of this species; and at first glance it seemed that substantial additions could be made to the descriptions already given. Closer examination, however, revealed the fact that in only a

* Nat. Hist. N. Y., Pal., vol. iii, p. 109, 1859.

few specimens could the plates be distinguished. It also seemed that there were two species, the fossils differing so much in size, gibbosity and general appearance; but further study failed to reveal any real differences. Some of the forms have a hemispherical calyx, and arms only three or four times as long as the cup, while others have a flat cup and arms five or six times as long; and yet the plates of the calyx, the joints of the arms, the pinnules and the cirri seem to be the same in the two varieties.

In the material from North Litchfield, the lower bed has much the larger forms, all of which are compressed. The upper bed has an abundance of the smaller ones, a few of which have the calyx gibbous, not flattened. The specimens from Jerusalem Hill are uncompressed and small. Wachsmuth and Springer consider *C. parvus* the young of *C. plumosus*; and it may be that it was these small, uncompressed specimens from the upper crinoid bed that Hall had under observation when he described the former species. If this assumption can be proved, it may be well to regard *C. parvus* as a variety of *C. plumosus*, as these small forms occur at a slightly higher geological horizon.

From a study of the specimens in the Yale University Museum, the following new data may be given: In no case does the length of the column exceed once and a quarter that of the crown, which varies from 5^{mm} to 32^{mm}. A large majority of those specimens which retain the column have very many unusually long cirri.

Several of the specimens have a feature which Bather states is found in some of the Camerata, and which he explains as being due to the fusing of the joints of the arms.* In these forms the arms are composed of long joints, seemingly single, with the upper and lower surfaces parallel and horizontal. In parts of the arm, every other joint bears two pinnules on the same side of the ray. This alternation of one- and two-pinnuled joints does not extend throughout the whole length of the ray, but in places it is every third joint that has this peculiarity. Toward the base the joints are normal, that is, one-pinnuled. In his description, Hall mentions the fact that some of the joints have two pinnules; but in his figure,† he represents most



Text-figure 8.—Anal sac of *Cordylocrinus plumosus*. a, right postero-lateral radial; b, left postero-lateral radial; c, first of anal series of plates. $\times 4$.

* A Treatise on Zoology, Pt. III. The Echinodermata, p. 116, 1900.

† Nat. Hist. N. Y., Pal., vol. iii, pl. 4, fig. 4, 1859.

of such joints as made of two, in this agreeing with Bather's explanation. The specimens under examination, although one is very well preserved, do not give the faintest trace of the separate joints; yet this explanation for the presence of the additional pinnules seems to be the most rational one yet offered.

Of the whole number of specimens examined, only one shows the anal tube mentioned by Hall. This tube is seen indistinctly in the photograph (pl. III, fig. 4; also text-fig. 3). The length of the tube is a little over half that of the crown.

Horizon and locality.—Upper third of the Coeymans limestone at Jerusalem Hill and at North Litchfield.

Cotypes in the American Museum of Natural History.

Order, ARTICULATA Wachsmuth and Springer.

Suborder, IMPINNATA Wachsmuth and Springer.

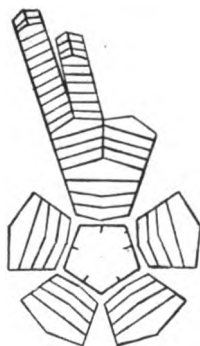
Family, *Ichthyocrinidae* Wachsmuth and Springer.

Genus, *Ichthyocrinus* Conrad.

Ichthyocrinus schucherti n. sp. Plate III, figure 1; text-figure 4.

Specific description.—Crown, including the incurved arms, an inverted, truncated cone with straight sides. Length and breadth equal, 19^{mm}, the greatest breadth being at the point where the arms become free. Infrabasals not shown. Basals five, pentagonal. Radials five, hexagonal, wider than long. Costals three in each ray, wider than long, one hexagonal, the other two pentagonal, the upper supporting two rows of distichals, the first three ranges of which are quadrangular and the last pentangular and followed by two rows of palmars. The palmars are of different numbers in the different rays and even in different parts of the same ray. Two or three of the palmars are included in the cup. Each costal and each distichal is wider than the plate of the same order below it, but in the palmars there is a decrease in the size of the successive plates.

Anal area not shown. Arms free from the second or third palmar, incurved. Each row of palmars divides at least once, making the number of branches forty. Column spreading slightly at the point of union with the crown. Joints of the column thin and equal near the calyx, alternating below, the larger ones about three times as high as the smaller. Length of column unknown.



Text-figure 4.—Diagram of *Ichthyocrinus schucherti*.

A single individual of this species was found by Professor Schuchert and was presented by him to the Yale University Museum. It differs from other species of the genus, principally in the shape of the crown, the straight sides of the cup being very characteristic. It resembles *I. lævis* more closely than any other, but differs from that species in the divisions of the rays and in the fact that the suture lines are not wavy.

Horizon and locality.—Lower third of the New Scotland limestone near Clarksville.

Holotype in the Yale University Museum.

Too little is known of the following Helderbergian crinoids to make definite statements in regard to their classification:—

Genus, *Aspidocrinus* Hall.

Aspidocrinus callosus Hall.

Aspidocrinus callosus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 123, pl. 5, figs. 13 and 14.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

Aspidocrinus digitatus Hall.

Aspidocrinus digitatus Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 123, pl. 5, figs. 19 and 20.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

Aspidocrinus scutelliformis Hall.

Aspidocrinus scutelliformis Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 122, pl. 5, figs. 15–18.—Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 228; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 402.

These species of *Aspidocrinus* present difficulties that are as yet unsolved. Hall described the forms as bases of crinoid cups, but Wachsmuth and Springer listed them doubtfully as crinoid roots. There are two reasons, at least, for thinking that they cannot be crinoid roots or basal expansions of columns. If they are basal expansions, the concave side must be the under side and this must have rested on the mud of the sea floor. One specimen of *A. scutelliformis* in the Yale University Museum has a bryozoan attached to this concave surface, proving that this surface could not have rested on the mud. If, on the other hand, these specimens represent the base of a cup, the presence of the bryozoan might be explained by supposing that its growth took place after the upper part of the dead calyx had been broken off but while the lower part still remained attached to the column.

Again, in undisputed examples of basal expansions, the lower or distal joints of the column enlarge and the segmentation of the column is continued into the upper part of the enlarged base. No such segments are visible in any of the specimens in question. In every good specimen, there is a clear-cut cir-

cular spot, generally dark-colored, which looks like the point of attachment of the column to the crown. With the exception of this spot, the cleavage lines of the calcite have obliterated all traces of organic structure.

Horizon and locality.—At the base of the Becraft limestone, or what was called the "Scutella limestone," at Clarksville, Countryman Hill and Schoharie.

Genus, *Brachiocrinus* Hall.

Brachiocrinus (*Herpetocrinus*?) *nodosarius* Hall. Plate IV, figures 7 and 8.

Brachiocrinus nodosarius Hall, Nat. Hist. N. Y., Pal., vol. iii, 1859, p. 118, pl. 5, figs. 5-7, pl. 6, figs. 1-3. — Wachsmuth and Springer, Rev. Palæocr., Pt. II, 1881, p. 229; Proc. Phila. Acad. Nat. Sci., vol. xxxiii, 1882, p. 413.

Herpetocrinus nodosarius Bather, Am. Geol., vol. xvi, 1895, p. 217.

In Hall's description, these fragments of crinoids are considered as arms or parts of arms; and this opinion was also held by Wachsmuth and Springer, in 1881. In 1895, Bather brought arguments to prove that they belong to columns, not arms,* and even gave a revised diagnosis of these New York forms as *Herpetocrinus nodosarius*. That he is not so certain of this classification as the earlier paper would indicate, may be gathered from the fact that in a later reference to the fossil, he lists *Brachiocrinus* as doubtfully synonymous with *Herpetocrinus*.†

Among other points in support of his first view, he remarks that "cirri composed of thick, beadlike joints which increase in size from the base to the middle and thence diminish to the extremities," characteristic of this species, are also found in *Herpetocrinus flabelliformis*, which occurs in the uppermost beds of the Silurian of Gotland.‡

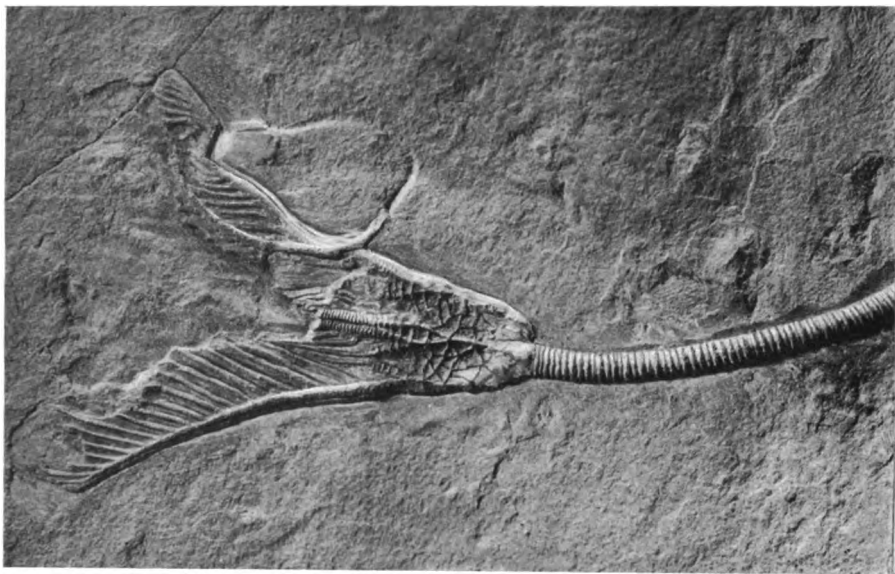
Most of the specimens in the Yale collection are so encrusted with silica that it is very difficult to get anything but general outlines; but one specimen is in fairly good condition and clearly shows the joints of the column and the cirri. The joints are slightly wedge-form and quite thin, giving to the fossil an irregular appearance, which is still further increased by the difference in the size of the joints of the cirri. The diameter of the cirri is so great that only every third or fourth joint is cirrus-bearing. The bulb-like process, varying in size and shape, is shown in several specimens at the end of the column. The question has arisen whether this bulb is at the base of the stem, or whether it is simply a thickening somewhere between the proximal and distal ends. If the latter were the case, the central canal should show at both ends of

* Am. Geol., vol. xvi, p. 213, 1895.

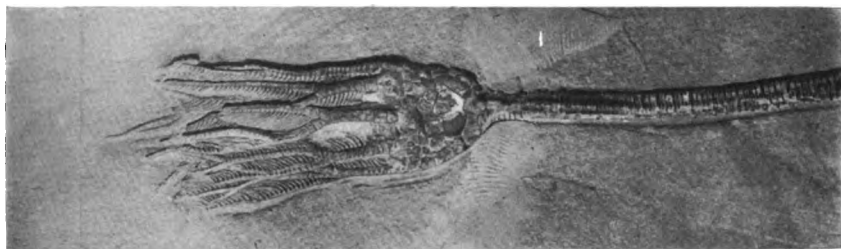
† A Treatise on Zoology, Pt. III. The Echinoderma, p. 146, 1900.

‡ Am. Geol., vol. xvi, pp. 215 and 216, 1895.

1



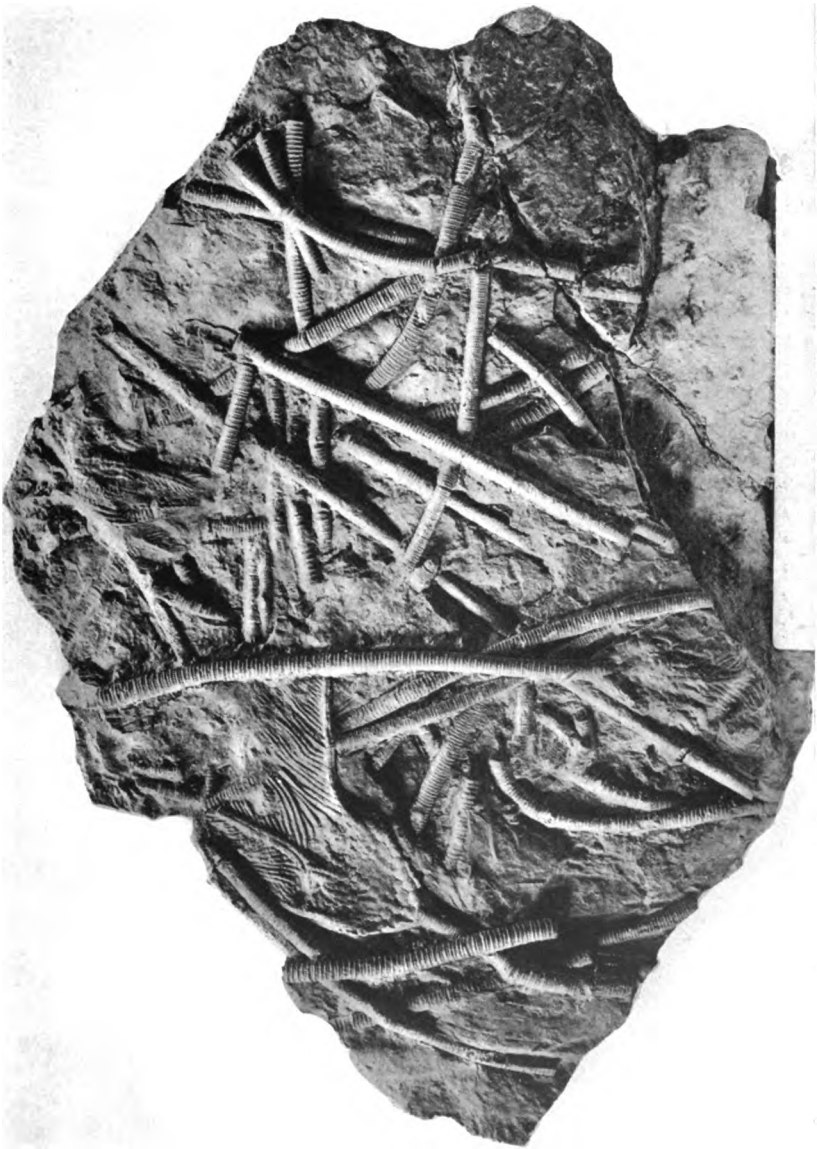
2



3



FIGURE 1.—*Melocrinus pachydactylus*.
FIGURE 2.—*Thysanocrinus arborescens*.
FIGURE 3.—*Mariacrinus beecheri*.

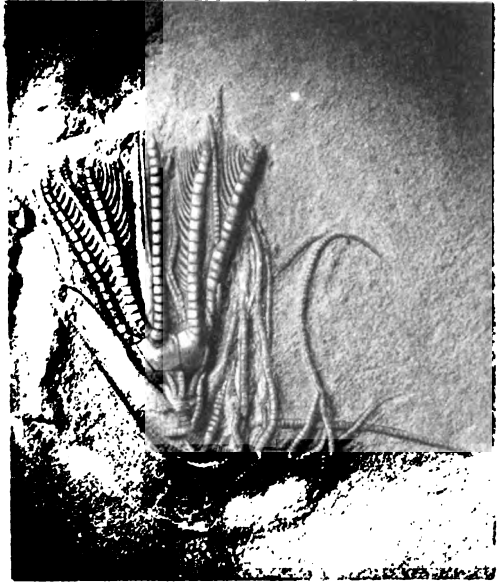


Melocrinus nobilissimus.

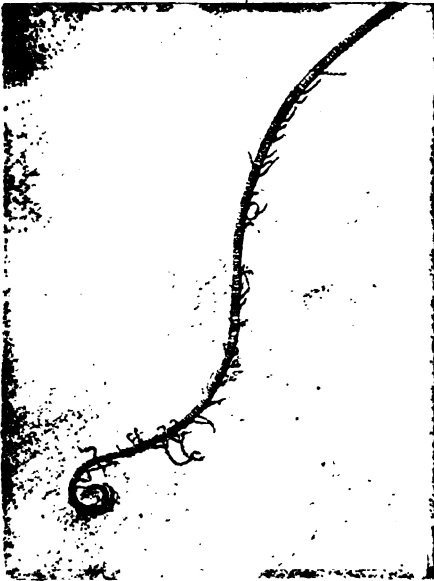
1



2



3



4



FIGURE 1.—*Ichthyocrinus schucherti*.
FIGURES 2 and 4.—*Cordyloerinus plumosus*.
FIGURE 3.—Stem of *Homoerinus scoparius*.

1



2



3



4



5



6



7



8



FIGURES 1-6.—*Edriocrinus pocilliformis*.
FIGURES 7 and 8.—*Brachiocrinus nodosarius*.

the specimens. Although one individual shows the canal very well at the distal end of the cirri and the proximal end of the stem fragment, this canal is not visible at the distal end of the bulb on any individual under observation. A small depression on one specimen looks like a cicatrix of attachment. Several individuals have the crescentic form of the joints of the column, as in *Herpetocrinus*.

Horizon and locality.—Lower part of the New Scotland limestone in the Helderberg Mountains.

Cotypes in the American Museum of Natural History and the New York State Museum.

EXPLANATIONS OF PLATES.

PLATE I.

FIGURE 1.—*Melocrinus pachydactylus*. About natural size.

FIGURE 2.—*Thysanocrinus arborescens* showing the hexagonal column and the branching of the arms. About natural size.

FIGURE 3.—*Mariocrinus beecheri* showing the thin stem joints near the crown and the separation of the two parts of the rays toward the distal end. About natural size.

PLATE II.

Slab containing stems and crowns of *Melocrinus nobilissimus*. Reduced a little more than one-half.

PLATE III.

FIGURE 1.—*Ichthyocrinus schucherti* showing the characteristic straight sides of the crown and the straight suture lines. $\times 2$.

FIGURE 2.—*Cordylocrinus plumosus* showing the long, crowding cirri and the one- and two-pinnuled joints of the arms. $\times 2$.

FIGURE 3.—Distal end of the stem of *Homocrinus scoparius* showing the coiling and the delicate cirri. $\times 2$.

FIGURE 4.—*Cordylocrinus plumosus*. The upper specimen on the plate shows the anal sac. $\times 2$.

PLATE IV.

FIGURES 1-6.—*Edriocrinus pocilliformis*. $\times 2$.

FIGURES 1 and 2.—Simple ordinary forms, basals and infrabasals fused.

FIGURE 3.—Cup showing fused basals as a prominent ring, also cicatrix of attachment.

FIGURE 4.—Cup showing ring of basals, not protruding, and high narrow radials.

FIGURE 5.—Cup showing radials, but basals indistinguishable from infrabasals.

FIGURE 6.—Cup showing basals and infrabasals fused and radials fractured transversely.

FIGURES 7 and 8.—*Brachiocrinus nodosarius*. $\times 2$.

FIGURE 7.—Portion of the column showing the bulb at the distal end and the beadlike cirri.

FIGURE 8.—A larger bulb with the first joints of two cirri attached.

AM. JOUR. SCI.—FOURTH SERIES, VOL. XX, No. 115.—JULY, 1905.

TABLE OF HELDERBERGIAN CRINOIDS.

Species with * also in the Siluric. Numbers refer to localities given below.	Coeymans.	New Scot- land.	Becraft.	Location of the Type.
<i>Aspidocrinus callosus</i> Hall.		1, 2		Holotype, Am. Mus. Nat. Hist.
“ <i>digitatus</i> Hall.		2		“ N. Y. St. Mus.
“ <i>scutelliformis</i> Hall.			2, 3, 4	Cotypes, Am. Mus. Nat. Hist.
<i>Brachiocrinus plumosus</i> (?) <i>nodosarius</i> Hall.		1, 2		“ Am. Mus. Nat. Hist. and N. Y. St. Mus.
<i>Cordylocrinus polydactylus</i> (Hall)	5, 7			“ Am. Mus. Nat. Hist.
<i>Coronocrinus polydactylus</i> Hall.		2		Holotype, N. Y. St. Mus.
<i>Edriocrinus pocilliformis</i> Hall.		3, 4		Cotypes, Am. Mus. Nat. Hist.
* <i>Homocrinus scoparius</i> Hall.				“ Am. Mus. Nat. Hist.
<i>Ichthyocrinus becheri</i> n. sp.	2, 5, 6, 7	3		Holotype, Yale Univ. Mus.
<i>Mariacrinus becheri</i> n. sp.	6			Cotypes, Yale Univ. Mus.
“ (?) <i>macropetalus</i> (Hall), referred pro- visionally to <i>Cordylocrinus</i> by Wachsmuth and Springer				
<i>Mariacrinus plumosus</i> Hall.	7			Cotypes, Am. Mus. Nat. Hist.
“ <i>ramosus</i> Hall.	7			Holotype, N. Y. St. Mus.
“ (?) <i>stoloniferus</i> Hall.		1, 2		“ N. Y. St. Mus.
<i>Marsupiocrinus tentaculatus</i> (Hall)		7		Cotypes, Am. Mus. Nat. Hist.
<i>Melocrinus nobilissimus</i> (Hall)				Holotype, Am. Mus. Nat. Hist.
“ <i>pachydactylus</i> (Conrad)	6, 7			Cotypes, Am. Mus. Nat. Hist.
<i>Platycrinus ramulosus</i> Hall.	2, 5, 6			?
	5			? Probably occurs in Cobleskill zone of the Manlius.
<i>Thysanocrinus arborescens</i> n. sp.	6			Holotype, Yale Univ. Mus.

1. The Helderberg Mountains.
2. Schoharie.
3. Clarksville.
4. Countryman Hill.
5. Jerusalem Hill.
6. North Litchfield.
7. Wheelock's Hill.

ART. V.—*The Petrographic Province of Central Montana;*
by L. V. PIRSSON.

Introduction.
Definition of the province.
Consanguinity shown by minerals.
Augite.
Biotite.
Hornblende.
Feldspars.
Absence of minerals.
Consanguinity shown in textural habit.
Chemical evidence of consanguinity.
General law of the province.
Application to the region.
Geographical arrangement of magmas.
Bearing on differentiation.
Regional progression of types,

Introduction.

THE fact that in certain areas of the world's surface the igneous rocks have common characteristics, which serve to ally them together and to define them from the rocks of other areas, is now well recognized by petrographers. These common features are sometimes expressed in the minerals, sometimes in the chemical composition of the magmas and sometimes in peculiarities of texture, but usually in a union of these qualities. In some cases these features are clearly marked, in others they are but slightly developed; nevertheless, like those indescribable characters which define a man as belonging to one nation rather than to another, they are easily recognized by the experienced eye.

The formulation of this principle, that the rocks of a given region may be thus genetically related, we owe to Judd,* and it has since been elaborated and applied with fruitful results to various regions by Iddings,† who developed it under the expression "*consanguinity of igneous rocks.*" Since then the idea has been applied to various regions by other petrographers; so, for example, Lacroix in a recent very interesting memoir on the alkalic rocks of northwest Madagascar, calls attention to the great belt of types rich in soda that stretches along the eastern coast of Africa.‡ Of all the various areas, however, where the consanguinity of igneous rocks has been studied and these relationships pointed out, there is probably none better known or more thoroughly investigated than that of South

* Quar. Jour. Geol. Soc., 1886, vol. xlii. p. 54.

† Origin of Igneous Rocks. Bull. Phil. Soc. Washington, xii, p. 128, 1892.

‡ Roches alcaline de Prov. Petrograph. d'Ampasindava Nouv. Arch. d. Muséum, 4^{me} Ser., vols. i et v, 1902, 1903.

Norway, and our knowledge of this region we owe for the greatest part to the keen perception and untiring labors of Brøgger, who has given the results of his work in that fine series of monographs which have become classics in the literature of petrography.

The fact that the outlying mountain groups east of the main chain of the northern Rocky Mountains are composed of rocks of a special character rich in alkalies, was pointed out by Iddings* in the work already referred to, although at that time little was known about them. Since then investigations and studies in the field and in the laboratory by a number of workers have thrown a flood of light upon this region. In the Black Hills of North Dakota the work of Caswell,† Jaggard,‡ Irving§ and the writer|| has shown a prevalence of types rich in alkalies with soda dominating the potash.

In Montana, the most southern of the eastern outlying groups fronting the great plains, is the Crazy Mountains, some of whose interesting rocks of alkalie types are known through the researches of Wolff.¶ North of this come the various groups studied by Mr. Weed and the writer; the Castle Mountains,** the Little Belt Mountains;†† the Judith Mountains;‡‡ the Highwood Mountains;§§ the Bearpaw Mountains;|| the Little Rocky Mountains¶¶ and lastly, on the border line between Canada and the United States, the Sweet Grass Hills,*** the last of the outliers. While some of these have been rather thoroughly investigated, there yet remains much to be done. The few types that have been described from the Crazy Mountains by Wolff, and its map††† showing the vast complexity of the

* Op. cit., p. 31.

† Microscopic Petrography of the Black Hills, 1876. U. S. Geog. and Geol. Surv., Rocky Mts. region. J. W. Powell in charge. Rep. on the Black Hills of Dakota, pp. 469-527, Washington, 1880.

‡ Laccoliths of the Black Hills, 21st Ann. Rep. U. S. Geol. Surv., Pt. iii, pp. 163-290, 1901.

§ Geology of the northern Black Hills. Ann. N. Y. Acad. Sci., vol. xii, No. 9, pp. 187-340, 1899.

|| Phonolite Rocks from the Black Hills. This Journal, 3d Ser., vol. xlvii, pp. 341-346, 1894.

¶ Bull. Geol. Soc. Amer., vol. iii, pp. 445-452, 1892. Bull. Harv. Mus. Comp. Zool., vol. xvi, pp. 227-233, 1893.

** Bull. No. 139, U. S. Geol. Survey, 1896.

†† 20th Ann. Rept. U. S. Geol. Surv., 1900, Pt. iii, p. 562. This Journal, 3d Ser., vol. i, pp. 467-479, 1895.

‡‡ 18th Ann. Rept. U. S. Geol. Surv., 1898, Pt. iii, p. 437-616.

§§ Bull. 237 U. S. Geol. Surv., 1905. Bull. Geol. Soc. Amer., vol. vi, pp. 389-422, 1895. This Journal, vol. ii, pp. 315-323, 1896.

|| This Journal, 4th Ser., vol. i, pp. 283-301, 351-362, and vol. ii, pp. 136-148, 188-189, 1896.

¶¶ Jour. of Geol., vol. iv, pp. 339-428, 1896.

*** This Journal, 3d Ser., vol. i, pp. 309-313, 1895.

††† Little Belt Mountains Folio, Montana. U. S. Geol. Surv., Geol. Atlas of U. S., No. 56, 1899.

dikes and sheets surrounding the main stocks of granular rocks, only serve to awaken general interest as to the character and relations of these rock masses, and it is to be greatly hoped that Professor Wolff will be able to continue his studies upon this interesting material and publish his results for the benefit of petrographers and for the understanding of the region. In the Bearpaw Mountains the researches of the writer upon the material collected during a hurried trip through them by Mr. Weed, which brought out such a variety of novel types of alkalic rocks, can only serve to demonstrate that this relatively large area must afford a fruitful field of study in the future; one whose complete investigation will add much to our knowledge of theoretic petrology and yield many interesting rock types.

The same must in large measure be true of the Sweet Grass Hills. The material studied by the writer gave types much like those of the Judith Mountains with hints of alkalic ones accompanying them, and the appearance of some specimens forwarded to Mr. Weed would seem to indicate that rocks of tinguoid habit occur there. Adding these facts to Dr. Dawson's* descriptions, it would seem as if they might consist largely of laccoliths probably with accompanying sheets and dikes similar in character and in rocks to those of the Judith and Little Rocky Mountains and the Black Hills.

Definition of the province.

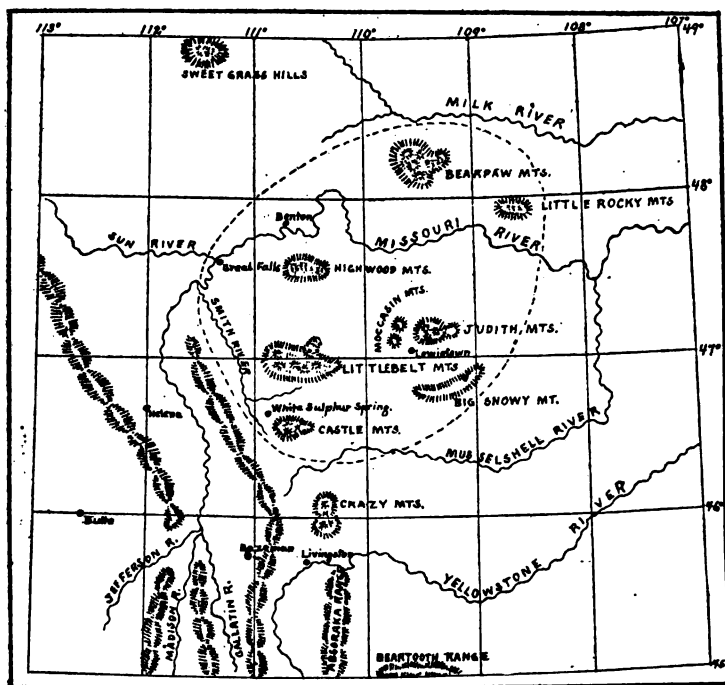
That part of this great region which has been studied by the writer, and with which he is therefore most familiar, lies in the center of Montana and embraces as its foci of igneous activity the Castle, Little Belt, Judith, Highwood, Bearpaw and Little Rocky Mountains. Since the general reader cannot be expected to be familiar with the geography of this region and the disposition of these groups, their arrangement with respect to one another and to the main chains of the Rocky Mountains is shown on the accompanying sketch map. It will there be seen that they lie in a roughly oval area stretching from the northeast towards the southwest, about 150 miles long by about 100 broad, in the middle of Montana and shown on the map by the dotted line. It is this region which it is here proposed to define as the petrographic province of central Montana; the consanguinity and general family relations of whose rocks it is intended to describe.

This paper then may be considered as a general summation along the line just mentioned of the work of the writer on these different mountain groups, presenting the broad petrologic features they possess in common. For the separate

* Rep. Canadian Geol. Surv., 1882-4, Pt. C, pp. 16 and 45.

details the reader is referred to the series of memoirs upon them whose list is given upon a foregoing page.

The evidences of consanguinity are to be seen in two ways, in certain mineral peculiarities and in the chemical composition of the magmas, the first being dependent upon the second in conjunction with the physical conditions attendant upon crystallization.



Map of Central Montana showing arrangement of mountain groups in petrographic province.

Consanguinity shown by minerals.

Augite.—One of the most marked features in regard to the mineral composition of this composite geographical rock family is to be seen in the augite. This has been already pointed out by Iddings,* but its application to this province is worthy of special mention.

The augite is of a distinct green color, very rarely pleochroic. It varies from very pale to a deep green. Brown or purplish augites are rare. They do occur in some of the lamprophyric dikes and flows but are exceptional, so that in a great preponderance of the rocks the green augite distinctly rules. Moreover this applies through the whole series from

* Op. cit., p. 131.

the most salic to the most femic types, the depth of color usually increasing somewhat towards the ferromagnesian pole. It is commonly supposed that the purplish color of augite is due to the titanite oxide it contains; and while this perhaps is true, it should nevertheless be pointed out that one of these green pyroxenes from the shonkinite of Square Butte, analyzed by the writer, contained over a half per cent of titanite oxide. It is also to be noted that titanite oxide occurs in all of these rocks, gradually increasing with the iron towards the ferromagnesian pole, yet the rocks towards this end still have the strong green color in the pyroxene. This is especially noticeable in the shonkinites of Yogo peak in the Little Belts, in the various occurrences in the Highwoods and in the Beaver stock and elsewhere in the Bearpaws, the TiO_2 ranging from 0.75 to 1.50 per cent, the silica falling as low as 46 per cent in the latter case. The occurrence of this green augite through the whole series is more strongly marked in the Highwoods than elsewhere and this local peculiarity did not escape Lindgren's notice and he makes especial mention of it,* not only for the Highwoods but for the other groups of the region with which he was acquainted. There is no notable exception to this rule in any of the Highwood rocks numbering several hundred occurrences studied by the writer, no matter how salic or femic the types may be.

This green augite is a marked feature then of this petrographic province, and in this respect it appears to differ from many other well-marked provinces of alkalic rocks. In the exceptional cases mentioned above, the augite is pale brown, strong purplish colors not having been noted, so far as the writer can recall, in the whole province.

In the salic rocks rich in alkalies, aegirite-augite appears: this is a marked feature of those of tinguoid habit; aegirite itself is rare. This seems to be due to the dominance of potash over soda, as will be shown in the discussion of the chemical peculiarities of the province. It is possible that the characters of the pyroxene, including its green color and non-pleochroism, are also due to this general chemical character of the magmas.

Biotite.—Throughout the province the biotites are the brown, strongly pleochroic variety—ordinary biotite. The red-brown biotites of the theralite rocks found in the Crazy Mountains to the southward do not occur, nor the pale phlogopites of the rocks rich in potash of the Leucite Hills in Wyoming as described by Zirkel† and Cross.‡ In some exceptional

* 10th Census United States, vol. xv, p. 726, 1886.

† Micro. Petrog. 40th Parallel Surv., vol. vi, p. 261.

‡ Igneous Rocks of the Leucite Hills and Pilot Butte, Wyoming; this Journal, vol. iv, 1897, p. 120.

cases of the lamprophyric dike rocks the biotites have darker borders, otherwise they are very uniform in all classes alike.

Hornblende.—This mineral is, comparatively speaking, of limited occurrence. It is found in an alkalic type in Square Butte syenite (pulaskose), and in the trachyandesite (adamellose) flow on North Willow creek in the Highwoods, and in some of the porphyries composing the laccoliths in the various mountain groups and in vogesite dikes in the Castle and Little Belt Mountains; but, with these exceptions, when it occurs it is clearly uraltic after augite. In this province augite rules in the vast majority of cases and even in the quartzose rocks (quarodofelic types) it appears rather than hornblende.

Feldspars.—It cannot be said that there is any specially marked evidence of consanguinity to be seen in these minerals so far as the author is able to detect. They do not present, for instance, any such remarkable features as those seen in the feldspars of the alkalic rocks of south Norway, shown in their greatest development in the phenocrysts of the rhombic porphyries. It is to be noted, however, that on account of the tendency for potash to dominate soda in the magmas, that orthoclase or soda-orthoclase is commonly the chief feldspar. Albite is of rare occurrence, even in the strongly alkalic types free from plagioclase, the one instance which is an exception to this—the porphyry of Lookout Butte* in the Little Rockies—being a notable exception. On the other hand, it is an interesting fact that in spite of the strong predominance of potash feldspar in so many occurrences of all kinds, microcline may be said to be absolutely wanting in the province. It is probably due to the comparatively recent and hypabyssal character of these rocks and the fact that they have not been subjected to dynamic pressures.

Absence of minerals.—The characters of a petrographic province are shown as much by the absence of some minerals as by the presence of others. In this one it is shown by the rarity or absence of minerals caused by the groups of rare earths—as they have, somewhat infelicitously, been called,—that is minerals marked by the presence of zirconia, thorina, cerium, lanthanum, didymium, columbic oxide, etc., etc. Even titanite is a rather rare mineral and zircon uncommon. Experience would seem to show that it is chiefly magmas rich in soda which these oxides accompany and that the potassic dominance in the magmas of the central Montana province tends to exclude them and to produce rocks lacking in the interesting minerals they give rise to.

* Jour. of Geol., vol. iv, p. 422, 1896.

Consanguinity shown in textural habit.

In some cases the consanguinity of the rock family is shown in the repetition of certain textural habits. Thus the pseudoleucite basalts of both the Highwoods and the Bearpaws closely resemble each other and both of them differ in habit from the leucitic rocks of other regions, from those of Italy for example. A most marked instance is also seen in the minettes of Highwood type (phyro-biotitic-cascadose). These occur not only in the Highwoods but thirty miles to the north-east on the Missouri River Mr. Weed collected similar rocks and they occur doubtless in the Bearpaw Mountains.* One of these from the Missouri River so exactly resembles the occurrence on Williams Creek on the south slope of the Highwoods and described in the memoir on the Highwood rocks† that hand specimens of the two cannot be distinguished from one another. So too, while each occurrence of shonkinite in the region, in the Little Belts, the Highwoods and the Bearpaw has its own peculiarities, yet taken together they form in sum total a well marked family group.

In the salic, feldspathic types, on account of their simpler composition these evidences of family relationship are less distinctly marked, and yet in the porphyries composing the laccoliths in all the groups of the province, there appears to be a tendency towards the repetition of a type with a certain textural habit difficult to describe but easily recognizable. It appears to be largely conditioned by a certain abundance, size and disposition of phenocrysts. There are many wide exceptions and variations of this, nevertheless the rule holds.

Chemical evidences of consanguinity.

The strongest evidences which show that the rocks of these various groups belong to a common family are to be found in comparing their chemical compositions. For this purpose a sufficient number of analyses are available for the Castle, Little Belt, and Highwood Mountains. For the Bearpaws there are enough to show the general character of the magmas, though more would be desirable. For the Judith and Little Rocky Mountains there is only one for each, but the general similarity of the types, shown by their petrographic study, is sufficient to indicate that they must agree in essential chemical characters, and as the rocks are of very similar nature and of simple types the two analyses must supplement each other fairly well. The Moccasin Mountains, which are two compound laccoliths, are practically a part of the Judith Mountains, and their rocks,

* Judging from Dawson's description (op. cit., p. 46) it seems probable that the same type also occurs in the Sweet Grass Hills.

† Igneous Rocks of the Highwood Mts., Bull. No. 237, U. S. Geol. Surv., 1904, p. 142.

as shown by Lindgren's* brief description and by specimens collected by Mr. Weed, are mainly composed of feldspar porphyries similar to those of the Judith Mountains.

In all 58 analyses have been made and published of rocks of this province, 15 by H. N. Stokes, 12 by W. F. Hillebrand, and one by W. H. Melville in the laboratory of the United States Geological Survey; 16 by the author and 14 under his direction by Messrs. H. W. Foote and E. B. Hurlburt in the laboratories of the Sheffield Scientific School in New Haven. It is not

Castle Mountains Magmas.

	1	2	3	4	5	6	7
SiO ₂	74.9	65.9	61.9	56.8	46.5	45.1	42.5
Al ₂ O ₃	18.6	16.8	17.3	18.3	10.5	15.4	12.0
Fe ₂ O ₃ .....	.7	1.6	2.3	1.6	4.4	2.8	3.2
FeO .....	.5	1.2	2.4	5.6	7.8	5.6	5.3
MgO	tr	1.5	1.8	3.6	10.6	6.5	12.4
CaO .....	.6	2.6	3.2	5.8	9.5	8.8	12.1
Na ₂ O	4.2	4.7	5.2	4.3	3.1	2.8	1.2
K ₂ O	4.6	3.1	3.8	3.3	1.5	2.8	2.7

Little Belt Magmas.

	8	9	10	11	12	13	14	15	16	17	18
SiO ₂	73.1	69.7	68.6	64.9	61.6	62.2	54.4	52.3	48.3	48.4	49.0
Al ₂ O ₃	14.3	15.0	16.1	15.4	15.1	15.8	14.3	14.0	13.3	11.6	12.3
Fe ₂ O ₃ .....	.5	.8	2.2	2.0	2.0	1.8	3.8	2.8	4.4	4.1	2.9
FeO .....	.3	.8	.4	1.6	2.2	2.4	4.1	4.4	3.2	3.6	5.8
MgO .....	.2	.7	.7	2.6	3.7	3.5	6.1	8.2	8.4	12.5	9.2
CaO	1.1	2.1	1.4	3.1	4.6	4.1	7.7	7.1	9.9	7.6	9.6
Na ₂ O	3.4	3.4	4.4	4.2	4.3	3.9	3.4	2.8	3.3	4.1	2.2
K ₂ O	4.9	4.4	4.9	3.9	4.5	3.9	4.2	3.9	3.0	3.2	5.0

Highwood Magmas.

	19	20	21	22	23	24	25	26	27	28	29	30	31
SiO ₂	65.5	59.2	58.0	57.2	56.4	55.2	51.9	51.7	49.6	47.8	48.0	46.0	46.1
Al ₂ O ₃	17.8	13.8	17.2	18.5	20.1	18.3	15.8	14.5	14.5	13.6	13.3	12.2	10.0
Fe ₂ O ₃ .....	.7	5.5	2.5	3.6	1.3	4.9	4.1	5.1	3.5	4.7	4.1	3.9	3.2
FeO	1.1	1.4	1.2	1.1	4.4	2.1	3.2	3.6	5.5	4.5	4.2	4.6	5.6
MgO	1.0	4.8	1.8	.7	.6	1.8	3.5	4.6	6.2	7.5	7.0	10.4	14.7
CaO	1.9	5.6	3.5	2.3	2.1	3.6	6.0	7.0	9.0	8.9	9.3	9.0	10.5
Na ₂ O	5.5	3.1	3.4	4.5	5.6	4.0	3.4	2.9	3.5	4.4	3.5	2.4	1.3
K ₂ O	5.6	4.2	10.1	8.6	7.1	6.4	7.7	7.6	5.6	3.2	5.0	5.8	5.1

Bearpaw Magmas.

	32	33	34	35	36	37	38	39	40
SiO ₂	66.2	68.3	57.5	52.8	51.9	50.0	46.5	68.7	57.6
Al ₂ O ₃	16.2	15.3	15.4	15.7	20.3	9.9	11.8	18.3	17.5
Fe ₂ O ₃	2.0	1.9	4.9	3.1	3.6	3.5	7.6	.6	3.5
FeO .....	.2	.8	.9	4.8	1.2	5.0	4.4	.1	1.2
MgO .....	.8	.5	1.4	5.0	.2	11.9	4.7	.1	.2
CaO	1.3	.9	2.6	7.6	1.6	8.3	7.4	1.0	1.4
Na ₂ O	6.5	5.5	5.5	3.6	8.5	2.4	2.4	4.9	5.8
K ₂ O	5.8	5.6	9.4	4.8	9.8	5.0	8.7	4.7	9.2

Little Rocky and Judith Magmas.

* This Journal, 3d Ser., vol. xlv, pp. 286-297, 1893.

worth while, however, to give all these analyses,* for some of them from a given area, for our purposes, would be merely repetitions of one another, and in this case only one is selected to represent this variety of magma. Only the essential elements are given and consequently the summations are omitted. In examining these tables of analyses the first thing that is evident is that in general, high silica, alumina and alkalies go together and are opposed to lime, iron and magnesia. This is of course merely a general truth applicable to all igneous rocks and not a special character of the province. The special and most obvious feature which distinguishes this district is in the relation of alkalies to one another and to silica. The potash dominates over the soda.

General law of the province.—Definitely stated it is this; *The petrographic province of central Montana is characterized by the fact that in the most siliceous magmas the percentages of potash and soda are about equal; with decreasing silica and increasing lime, iron and magnesia, the potash relatively increases over the soda, until in the least siliceous magmas it strongly dominates.* An inspection of the tables will show that there are but a few partial exceptions to this law in the 40 analyses given, and since all which are exceptions are given, the 18 omitted analyses would merely add the weight of additional figures to the truth of the law.

Application to the region.—It will be of interest now to examine this more in detail with respect to the various mountain groups. The Castle Mountains lie on the extreme southern border of the province; their next neighbor to the south is the Crazy Mountains group, and an examination of analyses from that district† shows that in the magmas soda strongly dominates the potash throughout the series. The writer has already shown‡ that the general Castle magma was one of a very salic character, in fact that of a granite, and that femic rocks play but a small role. Thus in the siliceous types we see the influence of the nearby Crazy Mountains' magma; the soda here slightly dominates the potash; we are on the edge of the province and the rocks are transitional. The relation to it is seen however in the most femic type, since here potash dominates the soda. As we go northward from here into the province the Little Belt rocks came next and its characters become more evident. In percentages potash begins to rule even in the siliceous types and in the extreme femic types this peculiarity is strongly marked. Only two exceptions are noted, both of which are given and both of which are narrow dikes. Their exceptional

* They may be found in the works previously cited.

† Bull. U. S. Geol. Surv. 168, pp. 120-124, 1900.

‡ Geology of the Castle Mountain Mining District, Bull. U. S. Geol. Surv. 139, p. 138.

position in the Little Belt series has been already discussed.* In the siliceous rocks the dominance of potash as one goes toward the center of the province sometimes expresses itself more strongly; thus in the granite porphyry of Wolf Butte on the extreme northern edge of the Little Belts the relations are $K_2O : Na_2O = 4.4 : 3.3$, as shown in an analysis not quoted above.

Next north beyond the Little Belts and near the center of the province are the Highwoods, and here its characters reach their highest development. The most siliceous type has equal percentages of soda and potash; there is only one occurrence, the syenite of Highwood peak; in the others the potash strongly dominates, increasing towards the femic end until in missourite it is 4 to 1. There is only one exception in this group which has been found, No. 28 in the table. It is the analcite basalt of Highwood Gap, occurring in narrow dikes.

The general line through the province to the northward now bends to the east toward the Bearpaws. Between the Bearpaws and the Highwoods there is an occurrence of igneous rocks in small stocks and dikes on the Missouri river. They have not yet been thoroughly investigated, but the study of sections made from specimens collected by Mr. Weed shows them of femic types like those occurring in the Highwoods. They are in fact largely minettes of Highwood type, as previously mentioned, and all their characters show that they closely conform to the general law and that potash rules.

Next beyond these come the Bearpaws, in which the general law of the province strictly holds. It is to be noted that towards the southern side the rocks are femic, and as we pass through the group we find on the northeast, on the edge of the province, salic (quardofelic) types occurring in laccoliths again as in Eagle Butte, the analysis of whose rock is shown in No. 32. Again here as on the southern edge the soda rises until it slightly exceeds potash.

Southeast of here, defining the edge of the province in that direction, are the Little Rockies, another laccolithic intrusion of salic types. There is some variation and the rocks pass into a tinguaitic phase. Exactly of the same character are the Judith Mountains; also a boundary group on the edge of the province, of salic types running into tinguaites. There is as yet only one analysis from each of these groups, one of a granite porphyry from the Little Rockies No. 39 and one of a tinguaitic (judithose) from the Judith Mountains. Thus they supplement each other and the general law holds true, the potash increasing as the silica falls. It is also to be noted that in neither of these boundary groups do any femic types occur.

* Petrography of the Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., Pt. iii, p. 576.

So far as is known, the Sweet Grass Hills off to the northwest agree with the last two groups, but the absolute confirmation of this must await future exploration and study. Moreover they are somewhat outside of the general area under discussion. In this connection however there might be mentioned Big Snowy Mountain, south of the Judith Mountains. This is evidently a large laccolithic uplift, and from the Judith Mountains the heavy white Carboniferous limestones dipping away from it are clearly seen. Intelligent mining prospectors, who have searched the mountain for ore deposits, have assured me that it is all limestone on top and that no porphyry is exposed. The laccolithic roof has evidently not yet been eroded away, but considering all the facts of structure and occurrence in this province, there can scarcely be reasonable doubt that a concealed body of feldspathic porphyry lies underneath the limestone dome.

Geographical Arrangement of Magmas.

From what has been already said, it is now evident that there is a rather orderly arrangement of magmas in the province. Around the outer edge they tend to be strongly siliceous, low in lime, iron and magnesia, and with the percentages of soda about equal to those of potash, and these magmas have usually marked their upward movement and intrusion by the formation of laccoliths. One can say in truth that the boundary of the province on the south, southeast, east, north and if it be extended to include the Sweet Grass Hills, on the northwest, is defined by laccoliths or groups of laccoliths of a rather definite type of magma. On the west the boundary is not yet well known and is perhaps not so clearly defined. At all events, in this direction it is eventually cut off by the main ranges of the Rocky Mountains, whose magmas, so far as we know them, are of a quite different character, belonging in fact to the granite-diorite series whose surface equivalents are rhyolites, andesites and basalts.

On the border line of the province thus defined femic types are rare or wanting. When they appear, however, they tend to assume the regional character and potash rises. As we approach the center of the province they become more numerous and of larger volume and as silica sinks the potash rises. This is shown by the occurrences of monzonite and shonkinite in the Little Belts and on its northern edge. Finally, in the central portion of the province in the Highwoods, on the Missouri river and in part of the Bearpaws the magmas are distinctly femic and rocks rich in ferro-magnesium components form the largest masses, are most numerous in occurrence and distinctly rule. There is still a recurrence of salic types, but they are of small volume and of diminished importance.

This arrangement of magmas over the region is of course not so well displayed as if there had been outbreaks of lava and igneous intrusions in every ten square miles of it and all conforming to the rule, but it is believed by the writer that one who reads carefully the facts previously stated and studies the map must be struck with the disposition of the magmas about a common center as shown in the mountain groups. It does not appear as if this could be mere chance; on the contrary, it certainly seems to point to an orderly arrangement of things according to some definite cause, whether we are able to discover the latter or not.

Bearing on Differentiation.—It will be noticed that this arrangement is contrary to what obtains in most cases of local differentiation such as those of Yogo and Bearpaw peaks and Square Butte in this province, in which the border zones are femic with a concentration of the salic components towards the center. Washington* has shown that at Magnet Cove the contrary is the case, the outer zone being more salic and the inner part of strongly femic types. An instance of this also occurs in this province in the "diorite" intrusion of Castle Mountain near Blackhawk,† which at the center is a monzonoid rock with 56 per cent of silica and grows steadily more siliceous towards the periphery until it becomes a quartzose porphyritic type. Other examples are described by Brögger‡ in Norway and Ramsay and Hackmann§ in Lapland.

Washington in discussing these cases|| is inclined to view them as results of processes of solution and crystallization in which the magma, composed of silica, alumina and alkalis, is the solvent, the others being the solutes, and the solvent being in excess tends to crystallize first at the outer margins. This might explain such cases of *local* differentiation as are seen in laccoliths like Square Butte, but it is clear that it could not be applied to whole regions. For granting for the moment that a parent body of homogeneous magma can form diverse smaller bodies by some process, it could not do so over wide areas by one of solidification; the facts demand that the cleaved products should remain liquid though these secondary bodies, after intrusion into place, might yield diverse products by crystallization. The writer is not inclined to believe, on the other hand, that pure molecular flow, which Becker¶ has shown must take place with great and increasing slowness, can be a sufficient

* *Igneous Complex of Magnet Cove*, Bull. Geol. Soc. Amer., vol. xi, p. 407, 1900.

† Bull. 139, U. S. Geol. Surv., pp. 134 and 140, 1896.

‡ Brögger: *Zeit. f. Kryst.*, vol. xvi, 1890, p. 45.

§ Ramsay and Hackmann: *Fennia*, vol. xi, No. 2, 1894.

|| Loc. cit., p. 408.

¶ This Journal, vol. iii. p. 21, 1897.

modus operandi on a vast scale. But within limits and with sufficient time it may be a factor of importance, and combined with convection currents and forced movements on a small scale due to the passage of heated gases, and on a large one to dynamic movements of the crust, a variety of agencies may be brought into play which may be sufficient to render a body of homogeneous magma, even if of considerable size, quite diverse in its parts. And it is to be clearly noted that this is quite independent of the question as to whether the magma shell of the molten earth (supposing there ever was such a thing) was ever homogeneous or not. This is purely an academic question and may always, as at present, remain a matter of mere speculation. Whether it was or not, the magmas underlying the crust are different now in different regions, and this is the basic fact with which the petrographer has to concern himself.

On the other hand, it is the writer's belief that it would be unreasonable to throw away such indications as those afforded above, that the distribution and occurrence of igneous rocks are not due to mere chance; to deny they are governed like other things in nature by definite laws and processes; to affirm that they are caused by mere haphazard heterogeneity of the underlying magma, and to thus dispose of the subject by relegating it to chaos.

In regard to *local* as distinguished from *regional* differentiation, we know something of the conditions and occurrences most favorable for its operation of the magmas in which it is most likely to occur and to predict some of the probable results of its operation. But in regard to the latter it does not seem to the writer quite reasonable to assume that agencies and processes that would be operative on a small scale would be necessarily applicable to vast bodies of magma underlying great regions. The writer has already discussed this phase of the subject in another place and it is not necessary to repeat it here.* But in the writings and speculations of many petrographers a good deal of confusion on this subject appears and the differentiation of huge "magma basins" presumably covering hundreds and even thousands of square miles, is discussed in the same terms and with appeal to the same supposed agencies as has produced visible results in a single dike, laccolith or other relatively small rock body. In the writer's opinion this is wrong and will only tend to throw discredit upon what has so far been produced that is of real value. It must be confessed that at the present time so little is known and so much remains to be discovered that any attempt, from the

* Igneous Rocks of the Highwood Mountains, Bull. 237 U. S. Geol. Surv., p. 188.

data in hand, to solve the problem of general differentiation over wide regions must be a mere speculation. While the physical chemist therefore is attacking the problem on one side, it remains for the petrographer, on the other, to gather data regarding the occurrences of igneous rocks and their interrelationships and characters over definite areas, and the present article can be considered as a contribution towards this end.

The Regional Progression of Types.

It is desired to call attention here to a phase of the occurrence of rock types in the province in the hope that petrographers may observe if it is of general application in different petrographic provinces.

In lieu of a better name it may be called the *regional progression of types*, and the idea involved in this term is as follows: while in a given province there are certain family characters serving to bind the various rock types into one clan, yet from place to place within its limits the magmas may vary greatly from each other, and there may be, as in the Montana province, a number of centers with complexes of their own. It is so to speak that the clan is made up of a number of families each of which consists of individuals. In traversing the area from one family to another, the observer will note that certain types which are rare or sporadic in the first will become numerous or even dominating ones in the second. Long before the second family is reached its types begin to appear, and as the area is approached they are likely to become more numerous, then attain their greatest frequency and die away beyond. Thus there is an overlapping of types and the rare one of a given center of igneous rocks becomes the common one of a neighboring center. It of course depends upon the gradual change in the character of the magmas.

Some instances of this which have been observed in this province are as follows. In the Castle Mountains a single sporadic case of a monchiquoid rock was observed.* Going northward into the Little Belts they begin to be more common, and the author has described them under the name of "analcite basalts,"† while still farther to the northward in the Highwoods these are exceedingly common rocks. They occur for the greater part in dikes but in the Highwoods in flows also. In the midst of the Castle rocks this type appeared out of place when considered only by itself, but if we consider it not as a member of the Castle family, but of the central Montana clan, its occurrence falls into order.

*Bull. 139 U. S. Geol. Surv., pp. 68 and 114, 1896.

† Petrog. Little Belt Mts., 20th Ann. Rep. U. S. Geol. Surv., Pt. iii, p. 543, 1900.

Again, in the Castle district the stock at Blackhawk described under the name of "diorite" has its central portion developed as a monzonoid facies, as may readily be seen by reference to its description and analysis.* In the Little Belts to the north monzonite occurs in a considerable mass at Yogo Peak,† and in the Highwoods‡ and Bearpaws§ it is a prominent type.

Or again, shonkinitic facies of rock masses are found at Yogo Peak in the Little Belts and in the stock at the head of Beaver Creek in the Bearpaws, while in the Highwoods this rock is the common type and found in numerous masses.

So also rocks of tinguoid habit do not occur at all in Castle Mountain or in the Little Belts in the southern part of the province. They first begin to appear in the Highwoods in the middle part; here they are rare, only a few occurrences being noted, but in the Judith,|| Little Rocky¶ and Bearpaw** Mountains which define the northern part of the province they are very common rocks.

Other instances might be cited but these are sufficient to indicate the idea involved. It is in intrusive rocks of various kinds of occurrence, and perhaps more noticeably in dikes, that this progression of types is seen. The extrusive rocks do not occur so generally in this province that it may be observed among them.

It would be a matter of interest to know if this progression of types is a peculiarity confined to this province and occasioned by the local distribution of magmas or whether it is of more general application. The writer has observed indications of it in other places, as, for instance, in central New Hampshire, where at Red Hill and Mount Belknap centers of alkalic magmas occur. These are indicated at long distances by sporadic dikes of bostonoid and camptonoid habits, the latter becoming very numerous at the actual centers. But outside of the central Montana area the writer has not that intimate acquaintance with other broad petrographic provinces which is necessary to be able to apply this idea to them, and it must be left to others. It would seem as if south Norway and central Italy and perhaps the Bohemian Mittelgebirge, which is being so ably investigated by Hibsche, might afford good examples.

Sheffield Scientific School of Yale University,
New Haven, Conn., December, 1904.

* Bull. 139, p. 89.

† Petrog. Little Belt Mts. p. 475.

‡ Bull. 237, p. 76.

§ This Journal, vol. i, p. 355, 1896.

|| 18th Ann. Rep. U. S. Geol. Surv. Pt. iii, p. 566, 1898.

¶ Journal Geol., vol. iv. p. 419, 1896.

** This Journal, vol. ii, p. 189, 1896.

ART. VI.—*Croomia pauciflora* Torr. An anatomical study; by THEO. HOLM. (With one figure in the text drawn by the author.)

MANY years ago *Croomia* was considered a member of the *Berberidaceæ* and an ally of *Berberis*, *Caulophyllum*, *Diphyleia*, *Jeffersonia* and *Podophyllum*,* with the admission, however, that the examination of a single seed did not disclose whether the plant was dicotyledonous or not, and that the affinity in either case remained obscure. Several years later the mistake was corrected by Gray himself and the genus referred to the *Roxburghiaceæ*.† Besides the American species there is another one in Japan: *C. Japonica* Mig., but these two are the only ones, known so far, of this singular genus. The monotypic *Stichoneuron* and the small genus *Stemona* Lour. (*Roxburghia* Banks) are with *Croomia* the only representatives known of the order. Habitually these genera are quite distinct, *Stemona* being a tall climber, the others low herbs; the floral structures have been carefully described by Gray, Bentham and Hooker, and Engler and Prantl. A more detailed account of the morphology of the flower as well as the anatomy of the vegetative organs of some species of *Stemona* has been given by Mr. Lachner-Sandoval.‡ In regard to *Croomia* Gray pointed out some few peculiarities in the stem-structure, sufficient to prove that its systematic position would have to be sought among the *Monocotyledones*, but otherwise the genus has not been studied from this particular point of view.

Having received some fresh material from Alabama, we have examined the internal structure of the vegetative organs of *Croomia*, and the following notes may be considered as supplemental to those of Mr. Lachner-Sandoval for illustrating the comparative anatomy of this peculiar little order. A few remarks upon the rhizome may, also, be inserted at this place.

As stated above, *Croomia pauciflora* is a low herb with a few green leaves and two- or three-flowered inflorescences near the apex of the single stem. The rhizome represents a sympodium; it is slender, horizontally creeping with stretched internodes and scale-like, membranaceous leaves. The terminal bud produces the aerial, flower-bearing stem surrounded at the base by three scale-like leaves, while a bud from the axil of the lowermost of these pushes out into a horizontal, subterranean branch, which continues the direction and growth of

* Gray, Asa: *Genera floræ Americæ bor.-orient. ill.* Vol. i, 1848, p. 90.

† Same: On the genus *Croomia*, and its place in the natural system. (*Mém. Amer. Acad. Sc.*, Ser. 2, vol. vi, 1859, p. 453, plate 31.)

‡ *Beitrag zur Kenntniss der Gattung Roxburghia.* (*Botan. Centralb.*, vol. i, 1892, p. 65.

the mother-rhizome. Dormant buds may be observed in the axils of some of the leaves of the horizontal portion of the rhizome. The roots are white, somewhat fleshy and sparingly ramified; they develop mostly below the nodes or, sometimes, a little above these.

In the Japanese species *C. Japonica* Mig. the habit of the plant is the same, but the flowers are single in the axils of the leaves, and the rhizome has no stretched internodes.

The internal structure of the vegetative organs of our species of *Croomia* shows several points of interest, when compared with the allied orders, and we will begin with the roots.

The roots.

The secondary roots are storage-roots with no contractile power; they are nearly glabrous and the thin-walled epidermis persists covering directly the cortical parenchyma, no hypoderm being developed. The cortex consists of about fifteen layers of thin-walled, starch-bearing cells, constituting a rather compact tissue. There is an endodermis of exceedingly small cells with thin walls and the Casparyan spots barely visible; it surrounds a continuous similarly thin-walled pericambium. Inside this are seven narrow rays of hadrome with one to two protohadrome vessels and about twenty, much wider, around a narrow central group of moderately thickened conjunctive tissue.

The thin, lateral roots show a like structure, but the cortex contains no starch and the endodermis is large-celled with the spots plainly visible; these roots were diarchic and the position of the protohadrome vessels was like that in the mother-root, inside the pericambium.

The rhizome.

When we examine one of the stretched, horizontal internodes we notice a smooth cuticle and an epidermis with the outer cell-walls moderately thickened. The cortex consists of about twenty-five layers, of which the peripheral two or three are collenchymatic, the others thin-walled and starch-bearing. No endodermis was to be observed, and the mestome-bundles possess only a weak support of stereome, which does not form a continuous ring around these. It is merely represented by a few, one to two, layers on the inner face of the mestome-bundles or on the sides of these; on the leptome-side this tissue is, also, poorly developed, sometimes entirely wanting.

The structure of the mestome-bundles is very irregular. They are apparently arranged in one or two circles, but several of these having fused together so as to form several groups of leptome and hadrome in immediate connection with each other, their number or real position could not be ascertained. As will be seen later, the mestome-bundles of the stem above

ground are leptocentric, and this structure is, also, to some extent to be observed in the rhizome, but much less regularly; the following variations were noticed. A few were collateral with the leptome and hadrome radially opposite each other and supported by stereome on both faces, the outer and the inner. Or the leptome was found to be surrounded by the vessels on the sides, and these bordering again on other groups of leptome with or without some support of stereome; in others the leptome constituted but one group with some vessels on the sides, while inwards it was separated from the pith by layers of stereome. Near the periphery of the cortex were observed two isolated, collateral and, in transverse section, orbicular mestome-bundles.

The central portion of the rhizome is occupied by a thin-walled, starch-bearing, solid pith.

A much more regular structure exists in the short, vertical internode below the uppermost of the three scale-like leaves which surround the base of the flowering stem. In this internode the fourteen mestome-bundles are located in an almost regular circle; nine of these are leptocentric and much larger than the remaining five, which are collateral and orbicular in transverse section. In regard to the disposition of these two forms of mestome-bundles, there is usually a small one between each two of the larger ones. They all are surrounded by stereome and separated from each other.

The stem.

A like structure was observed in the long internode of the stem above ground. This stem-portion is cylindric and solid; the cuticle is wrinkled and covers a small-celled epidermis, which is moderately thickened, perfectly glabrous and almost destitute of chlorophyll. The cortex consists of about fourteen strata of which the peripheral three or six are collenchymatic, and the innermost layer did not show the characteristic structure of an endodermis. A circle of thirteen mestome-bundles is imbedded in the cortex; each of these are completely surrounded by two to three layers of moderately thick-walled stereome, which enters into the leptome as a separate group in the larger bundles or merely as a bridge in the smaller ones (fig. 1). The mestome-bundles are all more or less oval in transverse section and contain a very large group of small-celled leptome, completely surrounded by a ring of scalariform and spiral vessels.

A pith of large, thin-walled cells without starch occupies the center of the stem.

By continuing our investigation to the structure of the axis of the inflorescence, we notice here the same arrangement of the tissues, but the structure is somewhat weaker. There is

only one peripheral layer of collenchyma and the stereome is reduced to a few isolated cells on the leptome-side instead of forming a closed ring around the bundle. The mestome-bundles themselves occur in a smaller number, from eight to nine, and are strictly collateral; they border on a narrow cen-

1

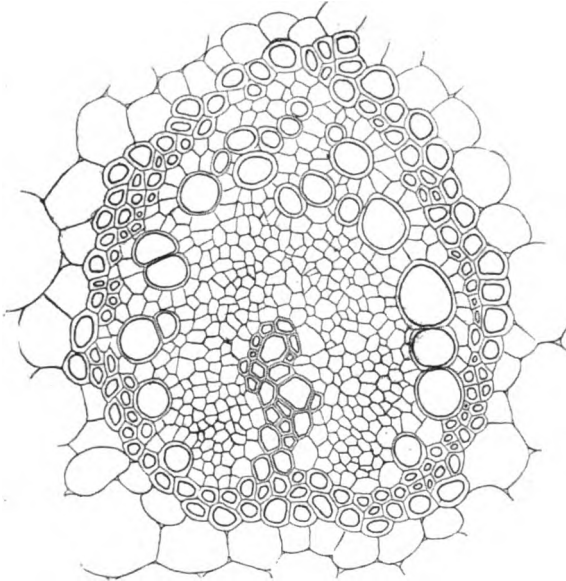


FIG. 1. Transverse section of a mestome-bundle from the stem above ground; 500 × natural size.

tral cylinder of pith. A corresponding structure is to be observed in the peduncle of the flower, but this possesses only two mestome-bundles, both of which are collateral.

The leaf.

The petiole: About three almost continuous, subepidermal layers of collenchyma surround the thin-walled cortex in which only a small amount of chlorophyll was observed. There is no stereome and no endodermis is differentiated. Seven collateral mestome-bundles traverse the petiole; they are arranged in a crescent corresponding with the outline of the petiole, and the median is the largest.

The blade: A thin smooth cuticle covers an epidermis with the outer cell-walls slightly thickened on both faces of the leaf-blade; the stomata are level with the epidermis and they are not parallel with the longitudinal axis of the blade; they occur only on the lower face. The chlorenchyma consists of five homogenous layers of oblong cells, which are not perpendicular, however, on the leaf-surface; this tissue is a little more

open on the lower face, thus representing some kind of pneumatic tissue. No stereome is developed, but there is a prominent ridge of colorless tissue above and below the midrib and the larger secondaries which becomes collenchymatic where it borders on the epidermis. But this is the only mechanical tissue in the leaf. The mestome-bundles are all collateral and single.

Characteristic of *Croomia pauciflora* is, thus, the structure of the mestome-bundles in the stem above ground, being leptocentric as well as in the rhizome, but simply collateral in the axis of the inflorescence, in the peduncles and in the leaves. The presence of similar leptocentric mestome-bundles is, moreover, characteristic of the genus *Roxburghia* in accordance with Mr. Lachner-Sandoval's investigations, cited above. This peculiar structure, where the leptome is surrounded, more or less completely, by the hadrome, is well known from various other orders among the Monocotyledones, but mostly from the rhizomes of these*; it is known, also, from mestome-bundles of certain Dicotyledones, which are located in the pith. In other words, it seems as if this peculiar structure of the mestome-bundles is principally observable in storage-organs and tissues: rhizomes and pith. But in the *Roxburghiaceæ* this structure is, furthermore, met with in the stem above ground instead of only in the rhizome.

Another peculiarity is the presence of stereome in the leptome, sometimes as an isolated group in the larger mestome-bundles or as a bridge in the smaller ones. The occurrence of thick-walled cells in the leptome has been described by several authors and defined as an abnormal thickening of the companion cells or, in some instances, of the sieve-tubes themselves instead of pertaining to the adjoining strata of stereomatic tissue. However it has been admitted that it is only occasionally that such thick-walled cells in the leptome are clearly distinguishable from true stereome-cells. In *Croomia*, as far as the writer has been able to ascertain, these cells were inseparable from the supporting layers of stereome; thus we have described them as belonging to this tissue.

It appears as if leptocentric mestome-bundles in stems above ground are uncommon, at least among the Monocotyledones. No such case has, so far, been recorded in the voluminous literature dealing with *Gramineæ* and *Cyperaceæ*, and Mr. Schulze does not mention the occurrence of such structure in any of the *Liliaceæ*, *Hæmodoraceæ*, *Hypoxidææ* or *Velloziaceæ*, which he has studied and described in his interesting paper on these orders.†

Brookland, D. C., April, 1905.

* Compare Chrysler, M. A.: The development of the central cylinder of *Araceæ* and *Liliaceæ* (Bot. Gazette, vol. xxxviii, p. 161, 1904).

† Engler's bot. Jahrb., vol. xvii, p. 295, 1893.

ART. VII. — *The Relative Proportion of Radium and Uranium in Radio-active Minerals*; by E. RUTHERFORD and B. B. BOLTWOOD.

THE experiments made by one of us* have shown that within the limit of experimental error the amount of radium present in radio-active minerals is proportional to the content of uranium. The amount of radium corresponding to each gram of uranium in a mineral is thus a definite constant which is of considerable practical as well as theoretical importance.

The proportionality between the content of uranium and radium in radio-active minerals strongly supports the view that radium is a decomposition product of uranium. According to the disintegration theory, the amount of radium per gram of uranium present in a mineral should be a constant whose value can be approximately deduced if the relative activity of pure radium and pure uranium is known.

In order to determine the amount of radium associated with one gram of uranium it is only necessary to compare the activity of the emanation produced by a standard quantity of pure radium bromide with that produced by a quantity of mineral containing a known weight of uranium.

In the experiments which are to be described, a standard solution of radium bromide was prepared from a specimen of radium bromide, which had been found experimentally by Rutherford and Barnes to give out heat at a slightly greater rate than 100 gram-calories per hour. The radium bromide was, therefore, probably pure. About one milligram of the salt was taken and weighed as accurately as possible on a balance. The weighing was confirmed by comparing the relative gamma-ray effect produced on an electroscope by the sample in question and the effect produced by a quantity of radium bromide weighing 23.7 milligrams. The determinations by the two methods were found in good agreement.

The known weight of radium bromide was dissolved in water and solutions were successively made up which contained 10^{-2} and 10^{-4} milligram of radium bromide per cubic centimeter. Of the more dilute solution a quantity equivalent to 1.584^{cc} was carefully weighed out, transferred to a glass bulb having a capacity of about 100^{cc} and diluted to a volume of about 50^{cc} with pure, distilled water. The bulb was sealed and allowed to stand for about 60 days in order that the maximum quantity of emanation might accumulate. At the end of this period the emanation was completely removed by boiling the

* Boltwood, Phil. Mag. (6), ix, 599, 1905.

solution and was transferred to an air-tight electroscope, in which its activity was measured. The observed activity corresponded to the emanation from 1.584×10^{-4} milligram of radium bromide, which was assumed to be equivalent to 0.926×10^{-4} milligram of radium.

The activity of the maximum or equilibrium quantity of emanation produced by the radium associated with one gram of uranium in a radio-active mineral was determined by the method which has already been described.* The mineral chosen was a very pure sample of uraninite from Spruce Pine, N. C., containing 74.65 per cent of uranium.

The activity of the emanation from the standard radium bromide solution was equal to 24.24 divisions per minute. The activity of the emanation from 0.1 gram of the mineral was equal to 14.45 divisions per minute, corresponding to 193.6 divisions per minute for each gram of uranium present. These values indicate that *the quantity of radium associated with one gram of uranium in a radio-active mineral is equal to approximately 7.4×10^{-7} gram.* One part of radium is therefore in radio-active equilibrium with approximately 1,350,000 parts of uranium.

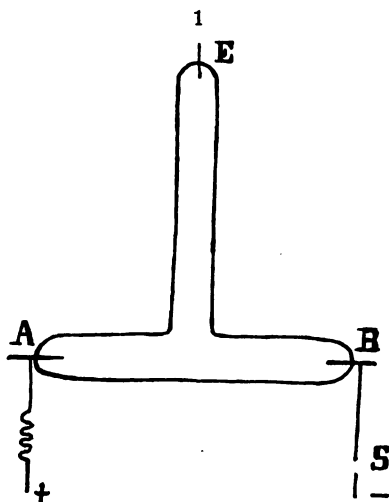
By the application of these numbers to the ordinary ores of uranium it is possible to determine their actual content of radium. Thus a high-grade pitchblende ore containing 60 per cent of uranium carries approximately 0.40 gram of radium, equivalent to 0.69 gram of radium bromide, per ton of 2,000 pounds. A low-grade 10 per cent uranium ore will contain per ton approximately 0.067 gram of radium, equivalent to 115 milligrams of radium bromide.

The amount of radium occurring with uranium is about the amount to be expected if uranium is the parent of radium, but a satisfactory comparison of theory with experiment is not possible until the relative activity of pure radium and pure uranium is more accurately determined. Experiments in this direction are in progress and the results will be given in a later paper. A method has been devised for determining in a radio-active mineral the proportion of the total activity due to the presence of uranium, radium and the other radio-active bodies. The results obtained lead to the conclusion that actinium is not a direct product of uranium in the same sense as is radium. An account of these experiments will be published later.

* Boltwood, loc. cit.

ART. VIII.—*Side Discharge of Electricity*; by JOHN TROWBRIDGE.

THE installation of a large storage battery of 10,000 to 20,000 cells presents many interesting problems in regard to insulation; and modern theories of ionization receive great support from a study of the phenomena observed in the region surrounding the poles of the battery. There is a great probability of an invisible ionization which is constantly taking place between the earth and the battery.

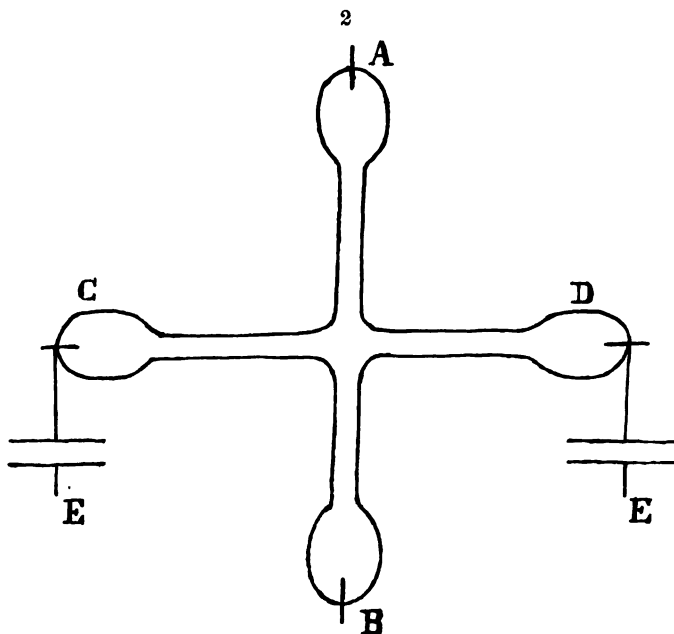


Such ionization immediately becomes visible in an interesting form of Geissler tube shown in fig. 1.

The terminal A is connected permanently with the pole of the battery through a large water resistance (several megohms). The terminal B is connected to the negative pole by a spark gap S. E is connected to the earth. At the instant the spark occurs a brilliant side discharge occurs between E and B. If the negative pole of the battery is permanently connected through the large water resistance to B, and A connected by a spark gap to the positive pole of the battery, the side discharge takes place between E and A. At the same time that these side discharges take place, a discharge passes between A and B. It is evident that the capacity of the region outside the battery, the room, and building charges up under the difference of potential between it and the poles of the battery, a difference

of potential which is greater than that between A and B, which are connected by the small resistance of the rarified gas.

This phenomenon suggests a photometric method of comparing the capacity of large condensers and also of obtaining the capacity of the immediately surrounding space. Fig. 2 represents a modification of the tube represented in fig. 1. To the arm C and D of the cross are attached the condensers which are to be compared. At the instant of the completion



of the circuit with the storage battery under the conditions mentioned above, two side discharges take place from C and D either to A or B. By bringing the light of these two simultaneous discharges into a suitable photometric arrangement, one can compare the capacity of the condensers to the degree of accuracy obtainable by ordinary photometric determinations. Since it is difficult to obtain an estimate of the capacity of large bodies of irregular shape and of large extent, this method may be of use. By a suitable vacuum tube and proper exhaustion the method does not require a large number of cells.

It was noticeable that when a stratified discharge was established between A and B fig. 1, there being no spark gap in the circuit except that of the rarified space between A and B,

fluctuating feeble discharges took place to earth through E. This phenomenon seems to indicate a discontinuity in the stratified discharge.

When the small spark gap, either at the positive or negative pole, is of a suitable length, the discharges between E and either pole of the battery succeed each other so rapidly that the side discharges to earth appear continuous. If a large condenser is substituted for the earth at E, one plate of the condenser being connected to earth, the time between each discharge is lengthened. This time of charging can be well illustrated by connecting condensers directly through a large water resistance directly to the poles of a large storage battery and allowing the condensers to discharge through a spark gap. The time of discharge can be regulated through a wide range and the arrangement can be termed an electric clock.

It is probable that in the case of lightning side discharges take place to the earth in the manner indicated by this method; the potential between the positively and negatively charged clouds rising to a higher value than that between the clouds; the earth space beneath the clouds acting as a localized capacity.

ART. IX.—*The Effect of High Temperatures on the Rate of Decay of the Active Deposit from Radium*; by HOWARD L. BRONSON.

In the course of a careful investigation of the decay of the active deposit from radium, some experiments of Curie and Danne* were repeated. These consisted in determining the change which high temperatures produce on the rate of decay of this active deposit. As a result of the following experiments, a different conclusion from that offered by Curie and Danne has been arrived at.

Miss Gates† showed that high temperatures produced at least a partial separation of the components of the active deposit from radium, owing to the fact that they are not all equally volatile. Curie and Danne verified this, and also found that the rate of decay of the active deposit apparently was permanently altered by exposure to temperatures between 650° and 1300° C. The following table gives some of their results:

t	θ
6 30°	29·3
8 30	24·6
10 00	21·0
11 00	20·3
12 50	24·1
13 00	25·4

Here t is the temperature in degrees centigrade to which the active deposit was raised, and θ is the "period," that is the time in minutes required for the activity to fall to half value. From this table it is seen that the rate of decay increased as the temperature was raised from 650° to 1100°, but decreased again at still higher temperatures. Curie and Danne also stated that the decay curves were exponential, and they therefore concluded that the rate of decay had been permanently altered.

In the following experiments the measurements were all made with an electrometer, and the "constant deflection method" described by the writer‡ was employed. The active deposit was collected on platinum wires by connecting them to the negative pole of a battery of 400 volts, and exposing them for several hours in the emanation from radium. After removal the wires were kept for a few minutes at the desired temperature in a small electric furnace, made by Dr. C. A.

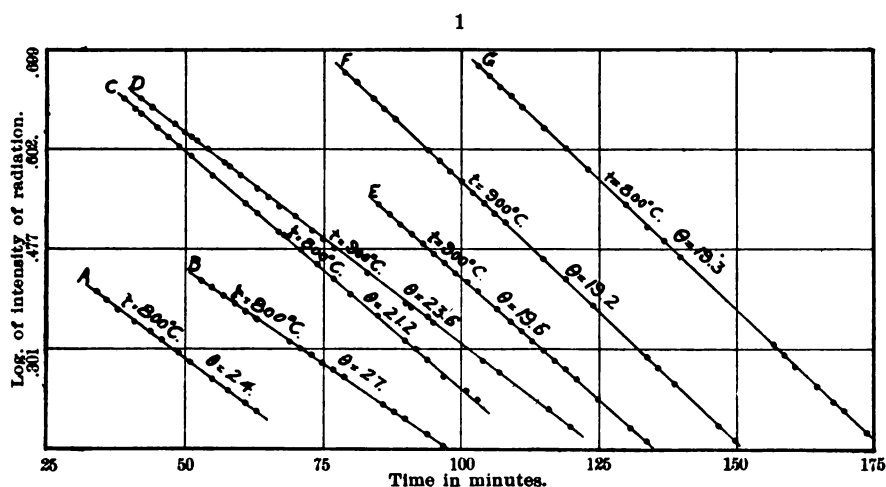
* Comptes Rendus, cxxxviii, p. 748, 1904.

† Physical Review, May, 1903.

‡ This Journal, Feb., 1905.

Timme of Berlin, and were then placed in the testing vessel. A calibration curve for the furnace had previously been made by the use of a platinum-rhodium thermo-junction.

A large number of experiments were made using several temperatures between 700° and 1100° C. An example of the kind of results obtained is given in fig. 1. A, B, C and G are four decay curves of the active deposit, which had been previously heated to about 800° C. In the case of D, E and F the temperature used was about 900° C. The time is reckoned from the removal of the wire from the

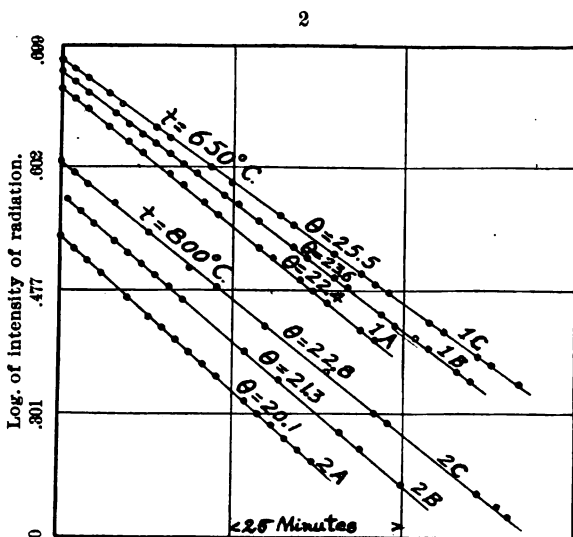


emanation. The first points on curves F and G should be at about 200 and 300 minutes respectively, as in these cases the wires were not placed in the furnace until several hours after their removal from the emanation. These curves are apparently exponential, as was found by Curie and Danne, but θ does not at all seem to be a function of the temperature, for its value seems just as liable to change when the temperature is kept the same as when a different temperature is used. In fact θ was found liable to take on any value between nineteen and twenty-seven minutes, and this was true for all temperatures between 700° and 1100° . Among these values of θ there were, however, a large number between nineteen and twenty-one minutes. This was nearly always the case when the wire was not heated until several hours after removal from the emanation.

Now Rutherford* has shown that, neglecting the first half

* Philosophical Transactions, 204, p. 196.

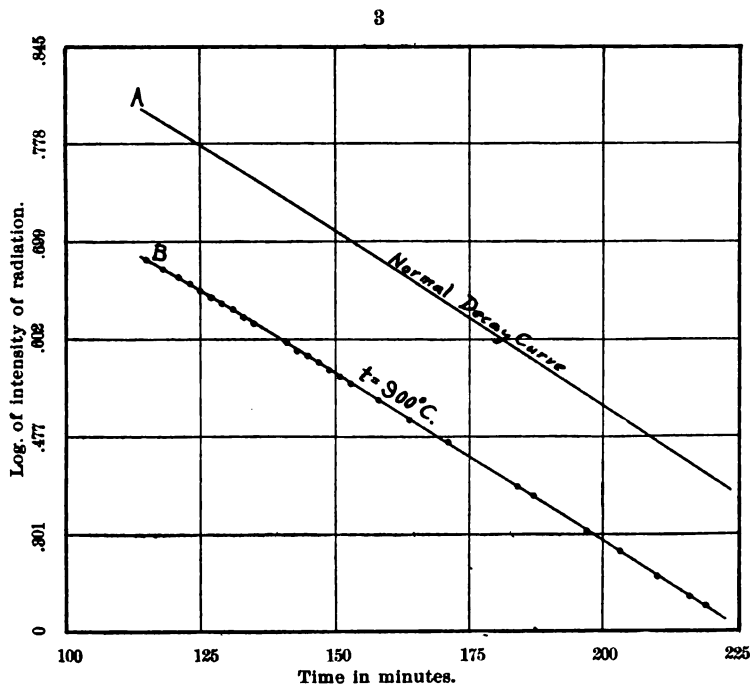
hour, the decay curve of the active deposit from radium is satisfactorily explained by assuming two successive products, radium B and radium C; the matter B giving rise to no rays, and the matter C to α , β and γ rays. Taking twenty-eight minutes as the decay period of one of these, he calculated that the period of the other must be twenty-one minutes. Theoretically it makes no difference whether the longer period belongs to the matter B or C, but the above mentioned experiments of Curie and Danne supplied the evidence which decided this question in favor of the matter C.



The fact that so many of the values of θ , obtained after heating the deposit, were in the neighborhood of twenty-one minutes, made it seem quite possible that the matter C had the shorter period, and not that its period had been changed by heating. Also the fact that the rayless change in the active deposits from thorium and actinium each have a longer period of decay than the change immediately following, possibly is evidence in the same direction. If this be the case, then all the larger values of θ must have been produced by mixtures of the two kinds of matter, B and C, in different proportions. This, however, would not give an exponential decay curve, but the period would continue to increase, since the ratio of the matter having the longer period to that having the shorter would increase with the time.

In order to see if this were the case, the decay of the activity of the heated deposit was measured over a long period of

time. Fig. 2 shows the result of two experiments of this kind. 1 A, 1 B and 1 C are three sections of the same curve, obtained after heating the active deposit to about 650°C . 1 A was taken immediately after heating, 1 B after about two hours, and 1 C after about four hours. The respective values of θ were 22.4, 23.6, and 25.5. In the case of curve 2, the temperature used was about 800°C . 2 A was taken immediately after heating, 2 B after about one hour, and 2 C after about



two and one-half hours, and the values obtained for θ were, respectively, 20.1, 21.3, and 22.8.

The above results furnished very strong evidence in favor of the supposition that the heating did not actually alter the rate of decay of the active deposit. In order to make this conclusive, the wire on which the active matter had been deposited was sealed, before heating, in a piece of glass combustion tubing. This prevented the escape of any volatile products, which in the previous experiments had evidently been the uncertain factor. By exhausting the glass before sealing, it was found that it would stand temperatures high enough to melt the copper wires, which were used in this case.

A number of experiments were made in this way, using the same temperatures as before, but in no case did θ fall below twenty-six minutes.

B, fig. 3, is the logarithmic decay curve, obtained when the active deposit was sealed in a glass tube and heated to 900°C . A is the normal decay curve for the active deposit. These curves are approximately parallel, showing that the rate of decay had not been measurably changed by a temperature of 900°C .

It is thus evident that temperatures between 700° and 1100°C . have very little, if any, effect on the rate of decay of the active deposit from radium. The results obtained by Curie and Danne and those given in the present paper are satisfactorily explained by assuming that radium C has the shorter instead of the longer of the two periods, and that radium B is the more volatile, but that in general a part of it still remains on the wire after heating.

The measurements made in this investigation also seem to show that both twenty-eight and twenty-one minutes are too large for the decay periods of radium B and C, and that twenty-six and nineteen minutes are nearer right. Experiments are at present in progress which it is hoped will settle this definitely.

In conclusion, I desire to thank Professor Rutherford for his many suggestions and kind supervision of this work.

Macdonald Physics Building,
McGill University, Montreal, June 5, 1905.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Amounts of Neon and Helium in the Air.*—SIR WILLIAM RAMSAY, in connection with previous investigations, has roughly estimated the amount of helium in the atmosphere at one or two parts per million, and the amount of neon at one or two parts per hundred thousand. He has now made more accurate determinations of these constituents, and finds one volume of neon in about 81,000 volumes of air, or .00086 per cent by weight, and one volume of helium in about 245,000 volumes of air, or .000056 per cent by weight. (In the published article the percentages are erroneously given as 100 times smaller than the above.) The method used in these determinations was based upon the absorption of gases by charcoal as recently studied by Sir James Dewar. The charcoal was kept at -100° , at which temperature neither neon nor helium is absorbed in appreciable quantities, while the other constituents may be almost completely absorbed by repeating the treatment. In this way about 2^{cc} of gas were left from the treatment of 18 l. of air, and after the residual air had been removed by sparking, the residue, which gave no spectrum of argon, was measured in a delicate apparatus. The neon was then condensed by charcoal at the temperature of liquid air in order to separate it from helium as far as possible, and the separate gases were afterwards measured. It appeared that this separation was a satisfactory one, although not absolute, and that the helium determination may be somewhat too high.

It is interesting to notice that Ramsay collected the lighter gases from 540^{cc} of liquid air, corresponding to about 400 l. of the gas, and that while he obtained a fair yield of neon and helium, he could find no evidence of the presence of hydrogen in this residue. The result appeared to show that there must be less hydrogen in the air than 1/500 of the combined neon and helium, but the author does not regard the experiment as quite conclusive.—*Chem. News*, xci, 203.

H. L. W.

2. *The Radio-activity of Thorium.*—An account is given by O. SACKUR of a product obtained by fractionating a mixture of barium and radium bromide obtained from 2.5 tons of thorianite. It was found by Hahn that the more soluble fractions of this mixture of bromides did not continually decrease in activity, as would be expected from the removal of radium, but, after a series of crystallizations, became more active. A strongly radio-active product was obtained from this liquid by precipitation with ammonia, and by solution in acid and precipitation with ammonium oxalate the activity was still further concentrated. It was found that the emanation from this substance lost one-half of its activity in 52–55 seconds, and that it consequently corresponds to the thorium emanation. This was confirmed by determining

the decay of its induced activity, which showed a period of 11.2 hours for the half value, while Rutherford has given about 11 hours as the characteristic period for the induced activity produced by the thorium emanation. It may be considered certain, therefore, that the substance obtained by Hahn gives off the thorium emanation; but, since comparative tests showed that the product possesses a power of emanation about 250,000 times greater than thorium, it is concluded that it contains a new radioactive element which produces the thorium emanation. The question arises whether two distinct elements may produce the same emanation, or whether the activity of thorium may be due to a mixture with this new element—a question which has not yet been decided.—*Berichte*, xxxviii, 1756. H. L. W.

3. *The Use of Quartz Apparatus for Laboratory Purposes.*—MYLIUS and MEUSSER of the Phys.-Techn. Reichsanstalt at Charlottenburg have investigated the action of various liquids upon quartz vessels by finding the loss in weight after such action. They find that water has no appreciable effect either at ordinary temperature or at 100°. In fact, the electrical conductivity of water may be diminished by boiling off the carbonic acid in these vessels. The vessels are attacked by alkaline liquids, and in this respect they appear to possess no advantage over glass. Dilute acids, with the exception of hydrofluoric, and concentrated sulphuric acid have no appreciable action at 100°, or at lower temperatures. Corrosion is produced by phosphoric acid when it is concentrated above 400°, and white silicilylphosphate separates. Quartz vessels possess the property of absorbing certain dyes from their solutions. The amounts thus absorbed are exceedingly small, forming a uniformly colored film when the vessels are rinsed, and this can be removed by the use of hot solvents.—*Zeitschr. Anorgan. Chem.*, xlv, 221. H. L. W.

4. *Permeability of Quartz Vessels to Gases.*—It has been observed that vessels of quartz glass are permeable to helium at temperatures below red heat, and BERTHELOT has recently found that other gases, for instance, atmospheric nitrogen, are capable of penetrating tubes of this material at a temperature of about 1,300°. This property of fused quartz will somewhat limit its applications for investigations at high temperatures.—*Comptes Rendus*, cxl, 821. H. L. W.

5. *Outlines of Inorganic Chemistry*; by FRANK AUSTIN GOOCH and CLAUDE FREDERIC WALKER. 12mo, pp. xxiv + 233 + 514. New York, 1905 (The Macmillan Company).—This textbook of elementary chemistry, a large and comprehensive work, is divided into two distinct parts, "inductive" and "descriptive." About twice as many pages are devoted to the latter part as to the former. It has been the aim of the authors to introduce the student to chemistry by consideration of the simplest and fewest things, and much attention has been paid to the inferences to be drawn from experimental phenomena. Part I takes up the consecutive experimental development of the principles upon which

chemistry rests. Only in the final chapter of this part is the notion of the atom introduced. Part II is arranged in accordance with a modification of Mendeléeff's Periodic System. Graphic symbols are freely used, and ionic terminology has been employed, although the extreme developments of the idea of free ions have not been made use of. Careful introductions to group characteristics, and full summaries covering the relations in detail, are given in this part of the book.

H. L. W.

6. *Spectroscopic Analysis of Gas Mixtures.*—Many investigators have endeavored to use the sensitive portion of the positive discharge in a Geissler tube as a qualitative means of determining proportions of gases in mixtures. Secchi, however, found that oxygen of air could not be detected in this way. E. Wiedemann has shown that mercury vapor masks the hydrogen and nitrogen spectra even when a large proportion of these gases are present. Collie and Ramsay found the method inoperative in the case of some gases. J. E. LILIENFELD, by suitable forms of tubes and proper arrangement of electrical circuit, finds that the method can be made extraordinarily sensitive, and gives the following table :

Smallest visible quantities.	Collie and Ramsay.	E. Wiedemann.	Lilienfeld.
He in N	10%	--	0.7 %
Ar in N	37%	--	0.932 % (in air)
N in Hg	--	approx. 30 %	0.7 %
H in Hg	--	" 30 %	0.7 %

The author shows that the theory of ionization explains the masking of the spectra of gases in a mixture. The presence of one gas prevents the dissociation of another gas.—*Ann. der Phys.*, No. 5, 1905, pp. 931–942. J. T.

7. *The FitzGerald-Lorentz Effect.*—FitzGerald and Lorentz, in reference to Michelson and Morley's experiments on the drift of the ether, suggested that the dimensions of the apparatus might be modified by its motion through the ether. Professors MORLEY and MILLER have, therefore, taken up the experiment anew and conclude their paper as follows: "We may declare, therefore, that the experiment shows that if there is any effect of the nature expected, it is less than the hundredth part of the computed value. If pine is affected at all, as has been suggested, it is affected to the same amount as sandstone. If the ether near the apparatus did not move with it, the difference in velocity was less than 3.5 kilometers per second, unless the effect on the materials annulled the effect sought. Some have thought that the former experiment only proved that the ether in a certain basement room was carried along with it. We desire to place the apparatus on a hill covered only with a transparent covering, to see if an effect could be there detected." The authors propose to make this experiment.—*Phil. Mag.*, May, 1905, pp. 680–685. J. T.

8. *The Normal Element.*—The weighty questions in regard to the conditions of stability of the mercuric sulphate do not appear to be solved. At present the silver voltameter is as reliable as the Weston element, and there does not appear any reason why those countries which have adopted the silver voltameter as a standard should give it up for the Weston element.—*Physk. Techn., Reichsanstalt, 1904.* J. T.

9. *Influence of Character of Excitation upon Structure of Spectral lines.*—If a Geissler tube is excited by electric oscillations, the fine spectral lines undergo a marked change, which is probably due to an increase of temperature arising from the electrical oscillations.—*Phys. Techn. Reichsanstalt, 1904.* J. T.

10. *On the Radio-active Minerals.*—In a paper upon this subject in the Proceedings of the Royal Society (A, lxxvi, 88–100) the author, R. J. STRUTT, summarizes his results as follows :

(1) The conclusion, that the amount of radium in a mineral is proportional to the uranium, is confirmed. The investigation of this point has brought to light the existence of uranium in some minerals not previously known to contain it, monazite, for instance.

(2) It is shown that thorium minerals invariably contain the uranium-radium combination. The observation is difficult to interpret, but it may possibly indicate that thorium is producing uranium.

(3) Helium never occurs except in very minute quantity unless thorium is present. The helium of minerals, therefore, is probably produced more by thorium than by radium.

(4) Thorium minerals vary much in emanating power. Some retain nearly all their emanation, others give off large quantities.

11. *On the Absence of excited Radio-activity due to temporary Exposure to γ -rays.*—This subject is discussed by J. J. Thomson and by H. A. Bumstead in brief articles published in the Proceedings of the Cambridge Philosophical Society, vol. xiii, part 2 (pp. 124, 125–128). Thomson says :

“Experiments were made to see if the radiation given out by metals could be temporarily increased by exposure to the radiation from radium. The method used was to measure the saturation current inside a closed metallic vessel, then to place a sealed glass tube containing 30 mg. of radium bromide inside the vessel and leave it there for times varying from one hour to ten days ; the radium was then removed and as soon as possible afterwards the saturation leak again measured ; experiments were made with vessels made of lead, brass, tin, but no increase in the saturation current attributable to exposure to the radium was ever detected. The measurement of the saturation current took at least five minutes after the removal of the radium, so that a very short-lived increase might escape detection by this method.”

The last mentioned point was independently investigated by Bumstead, who experimented with copper, lead, tin and uranium nitrate by a method specially devised for the purpose, but also without positive results. The author remarks :

"With the four substances tested, therefore, the result is negative. If they retain the power of giving out any rays capable of penetrating 0.7^{cm} of air and 0.00005^{cm} of aluminium, for 0.009 seconds after exposure to the β - and γ -rays from 30 milligrams of radium, these rays must be considerably less intense than those due to a layer of uranium salt whose surface-density is 1 milligram per square centimeter."

12. *Handbuch der Spectroscopie*; von H. KAYSER. Dritter Band. Pp. viii, 604; 3 plates, 94 figures. Leipzig, 1905 (S. HIRZEL).—Upon the appearance of the first volume of this work on Spectroscopy by Professor Kayser, a somewhat extended notice was published in this Journal, giving an outline of the whole plan (see vol. x, 464, 1900). Since then the second volume has appeared, followed now by the third. So thorough and exhaustive, however, is the work which the author is doing, that it has been found necessary to enlarge the original plan and devote two volumes instead of one to the subject of absorption, here discussed. The present volume contains the description of methods and of apparatus for the investigation of absorption spectra, a discussion of our present knowledge in regard to the connection between absorption and the constitution of the substance; and, finally, a presentation of the results of observations both for inorganic and artificial organic substances. The remainder of the subject, reserved for the next volume, includes the discussion of the natural organic coloring materials, both vegetable and animal, and also the phenomena connected with absorption; that is, dispersion, fluorescence and phosphorescence. The devotion with which the author has given himself to the subject and the thoroughness of his treatment of the entire subject matter are both noteworthy. In the preparation of the first volume he has had the assistance of Professor W. N. Hartley, of Dublin, who discusses very fully the question of the connection between constitution and absorption, where the author regarded himself as not sufficiently informed in reference to the chemical side to enable him to handle it satisfactorily. It needs hardly to be said that this chapter (pp. 144–316) shows the same degree of completeness and careful handling which characterizes the whole work.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey, Charles D. Walcott, Director*.—Recent publications by the U. S. Geological Survey include the following:

FOLIOS: No. 120, Silverton Folio, Colorado. This includes a description of the Silverton Quadrangle by WHITMAN CROSS, ERNEST HOWE and F. L. RANSOME; also geography and general geology of the Quadrangle by WHITMAN CROSS and ERNEST HOWE.

No. 121, Waynesburg Folio, Pennsylvania, by RALPH W. STONE.

BULLETINS. No. 243. Cement Materials and Industry ; by EDWIN C. ECKEL. 395 pp., 15 plates.

No. 255. The Fluorspar Deposits of Southern Illinois ; by H. FOSTER BAIN. 75 pp., 6 plates.—This bulletin gives an account of the fluorspar mines in Hope and Hardin counties in the extreme southern part of Illinois. The principal mines are near Rosiclare, Elizabethtown and Cave-in-Rock on the Ohio river in Hardin County. The discovery of the deposits goes back to 1839, although the material was not definitely mined until the early 70's. The author discusses the geology of the region in detail, and shows that the deposits of fluorspar, with the accompanying ores of lead and zinc, are vein deposits occurring along faulting fissures. The amount of fluorspar produced from the region in 1903 was 18,360 short tons, as compared with 29,000 tons from Kentucky and 628 from Arizona and Tennessee. The highest grade is used in the enameling, chemical and glass trades. The second grade is used in steel making, being used in open-hearth work because of the great fluidity which it gives the slag. Twenty thousand tons are used annually in this work. The lowest grade is used in foundry work, and there seems to be an almost unlimited market for it.

WATER SUPPLY PAPERS. No. 126. Report of Progress of Stream Measurements for the calendar year 1904. Prepared under the direction of F. H. NEWELL, by N. C. GROVER and JOHN C. HOYT. Part III, Susquehanna, Patapsco, Potomac, James, Roanoke, Cape Fear and Yadkin river Drainages.

No. 260. Contributions to Economic Geology, 1904 ; S. F. EMMONS, C. W. HAYES, geologists in charge. 620 pp., 4 plates, 25 figures.—The prompt and liberal return which the Geological Survey makes to the country at large for its pecuniary support is well shown by the numerous publications, appearing each year, which to a greater or less extent are devoted to Economic Geology. The publications of 1904 of this character, for example, included a Monograph by Van Hise; ten professional papers, chiefly on ore deposits in different regions; three bulletins and two folios, the last on the Globe and Bisbee Districts in Arizona. The present bulletin is the third bearing this title, its predecessors being Nos. 213 and 225, for the years 1902 and 1903. The object of these particular bulletins is to bring before the public, with all possible promptness, the economic results obtained by the Survey parties. Many of the subjects here presented are to be more fully discussed in other papers, appearing independently. The production of gold and silver are naturally presented at length; also that of tin, copper, zinc, lead and iron. Special chapters are given to some of the rare elements, as molybdenum, vanadium and uranium in Utah, etc. Coal, oil, gas and salt also form the subjects of special chapters. Many different authors contribute to the volume.

2. *Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains ;* by N. H. DAR-

TON. 433 pp., 4to, 72 plates, 18 figures. U. S. Geological Survey, Professional paper 32.—The area covered by the discussion in this volume embraces nearly all of South Dakota, Nebraska and Kansas, and extends westward to central Wyoming and Colorado. Over most of the region the rolling plains of the eastern portion rise gradually and uniformly to the westward. The geological structure is comparatively simple for the most part, with the exception of the Black Hills region in South Dakota and portions included of the Big Horn and Laramie Ranges in Wyoming and Colorado. The geological features are very fully presented in the first half of the present volume, the descriptions being based upon work by numerous geologists in the past, supplemented by that of Mr. Darton and his assistants. Numerous excellent views from photographs, and also geological maps and sections, accompany the text. The chief interest of the investigation, however, lies in the question of water supply, which in many parts of the region is very deficient and must be supplemented where possible by artesian wells. Great numbers of these have already been sunk, many of them with excellent results, and the study that Mr. Darton has made so carefully of the region gives promise that still more will be accomplished in the future. Although the rocks of Cambrian, Ordovician, Carboniferous and Jurassic age are believed to underlie the entire area, almost no wells exist lower than the Cretaceous, and the water horizon of the Dakota sandstone is the most widely extended and the most useful. The author states that over a thousand deep wells have been sunk east of Missouri River most of which are from 500 to 1000 feet in depth and yielding a large supply of flowing water, most of which is used for irrigation. The aggregate flow from these wells is estimated to be about 7,000,000 gallons a day. From the Fox Hills-Laramie formation the supply is much more limited. The Tertiary deposits also yield useful wells, particularly in the Denver basin. Finally, the alluvial deposits of the Quaternary afford large quantities of water from limited depths (5 to 50 feet), while the tubular wells in east South Dakota and east Nebraska bring the water of the glacial drift mainly at the base of the till.

The great pressure under which the water exists is a point of much interest and shows that it must owe its origin to an altitude some thousands of feet above. Several wells in eastern South Dakota, for example, show surface pressures over 175 pounds to the square inch, and two are a little over 200 pounds; the latter indicating a pressure of 780 pounds at the bottom of the well. The theoretical hydrostatic pressure is, however, much diminished by the leakage of water to the east and south. Full details are given in the volume in regard to existing wells, and the work closes with a chapter upon the Economic Geology of the region, that is, the supplies of coal, oil, gas, salt, etc.

3. *Origin of the Channels surrounding Manhattan Island, New York*; by W. H. HOBBS. Bull. Geol. Soc. America, xvi,

pp. 151-182, plate 35.—The author has made a careful study of the data now obtainable in regard to the various channels around the Manhattan Island, with a view to deciding as to their probable origin. In 1881 the subject was discussed by J. D. Dana* and their formation ascribed to the presence of belts of limestone whose erosion was believed to explain the topographic features. Hobbs, however, concludes that there is no sufficient evidence of a correspondence between the directions of belts of limestone, or dolomite, and those of the various channels; on the contrary, he regards them as owing their origin to lines of jointing and displacement. The account of Julien is appealed to, giving the location and orientation of the principal dikes on the island, which quite generally run along the direction of the avenues. Julien shows that the orientation of the drainage has been largely determined by the planes of fracture. Julien has also shown that, besides these, there is a system of cross faults nearly at right angles to the avenues, or, in other words, along the cross streets. Thus the fissure planes occupied by the dikes, and the perpendicular series often occupied by quartz lenses and pegmatite, both correspond very closely in their direction with the two series making up the main drainage system. The observations of the author also show that many of the most prominent joint-planes in the rocks of the island have the direction of the cross fissures, $N80^{\circ}W$. He concludes that "the rôle of the dolomite in fixing the locations of the present channels would thus appear to have been a subordinate one, excepting in so far as the direction of its boundaries has been determined by its fissure planes."

4. *The Isomorphism and Thermal Properties of the Feldspars*. Part I, Thermal Study; by ARTHUR L. DAY and E. T. ALLEN, pp. 13-75. Part II, Optical Study; by J. P. IDDIGS, pp. 77-95. Plates I to XXVI. With an introduction by GEORGE F. BECKER, pp. 4-12. Publication No. 31 of the Carnegie Institution of Washington.—The first part of this volume gives the complete presentation of the results obtained by Day and Allen in their very important work upon the thermal relations of the feldspars. This is accompanied by a series of twenty-six beautiful plates illustrating the crystallization of the various compounds and the effect of very high temperatures upon them. An extended abstract of this paper has already been given in the number of this Journal for February, 1905 (pp. 93-142).

Part II gives the results of an optical study by Iddings of the series of lime-soda feldspars synthetically obtained by crystallization in open crucibles from fused constituents. In addition to the detailed description of thin sections of the individual compounds, a general summary is given which contains some points of so much importance in petrography that we quote largely from it:

"The results of these synthetical experiments agree closely in some respects while differing in others. They agree in general

* This Journal, xxi, 25, 443; xxii, 313, 1881.

in the habit and arrangement of the crystals of the different feldspars produced, while differing in the size of the crystals of the various feldspars according to their composition. These results have an important bearing on the problem of texture and granularity in igneous rocks.

First, as to the habit of the feldspar crystals produced from solution of the feldspar constituents without admixture of other material. So far as can be determined by microscopical study of the sections, the crystals are in most cases blade-like in form; that is, they are elongated plates. They vary, however, from one extreme to another, being in some cases equidimensional plates of extreme thinness, in other cases prisms, elongated in one direction with the other two dimensions equal. The development of these forms takes place in feldspars of various compositions, and appears to be chiefly a function of the rate of crystallization and not of the chemical composition of the feldspar, except as this modifies the viscosity of the solution. It is not possible to recognize any fixed relation between the habit of the crystals and the composition of the feldspar. This is, of course, in accord with the well-known isomorphism of the feldspar group.

The common mode of crystallization in these preparations is that of spherulitic aggregations, more or less completely developed in spherical forms.

The elements of the spherulites are bundle- or sheaf-like aggregations of long, thin blades, which blades lie nearly parallel to one another in the middle or narrower part of the bundle, and diverge at the ends into fan-like or plumose forms. Several of these bundles or blades cross one another at the middle, and when there are a sufficient number of bundles, or when they diverge sufficiently, a completely spherulitic aggregation results.

In some cases a spherulite consists of bundles or prisms that extend uninterruptedly from the center to the outer margin, the rays of the spherulite being nearly straight. In other cases the spherulite is a composite of divergent bundles shorter than the radius, which have been added to one another as though new plumes had started from the ends of earlier ones.

In most cases the middle portion of the feldspar bundles consists of stouter crystals than the outer parts. It also appears that the middle portion is more prismatic, in certain cases somewhat cuboidal, the outer parts becoming delicately tabular. This, with the divergence in position, explains the spread of the outer part of the sphere. There is a great increase in the number of individual crystals in the outer portion of the spherulite, and in some cases the crystals also increase in size in the outer part.

The shapes of the crystals are due to the flattening of the crystal parallel to the second pinacoid (010), and its elongation parallel to the crystal axis a . The outlines of the plates appear to conform to traces of several pinacoids in the zone of the b axis, (001), ($\bar{2}$ 01), (101), (201), ($\bar{3}$ 04), ($\bar{2}$ 03), not all of these occurring together. It is quite probable that pinacoids in the zone of the c axis also may be developed, but they were not recognized.

Bladed forms in some cases prove to be aggregates of thin plates not strictly parallel to one another in the plane of flattening, so that the blade is curved and not straight in the direction of its longest axis.

In some spherulites the component crystals are prisms throughout, with no tabular flattening. The number of crystal prisms increases from the center of the spherulite outward by the development of new prisms at slightly divergent angles, in arborescent arrangement.

The most complex arrangements are produced by twinning and divergence combined, resulting in feather-like aggregates. Long, narrow, tapering blades in albite twins form a shaft, elongated parallel to the crystal axis a , on two sides of which diverge at a slight angle a double set of thin blades, like barbs. These consist of branched smaller blades or prisms, like barbules, the branch prisms having approximately the direction of the crystal axis c . The two sets in each "barb" are apparently related to one another as the halves of a manebach twin. The small prisms are composed of many subparallel plates flattened in the plane of the second pinacoid (010). These correspond to barbicels in a feather.

With respect to the size of the crystals it is extremely significant that pure anorthite (An) develops in comparatively large plates, 5^{mm} thick and 20 to 30^{mm} long, in a few hours, whereas the more sodic the feldspar the smaller the individual crystals formed under almost the same conditions of cooling. Thus with oligoclase (Ab,An) the individual crystals composing a bundle of blades are considerably less than 0.01^{mm} thick, probably about 0.001^{mm}, a difference in thickness when compared with anorthite of about 5,000 to 1. This as shown elsewhere is due to the greater viscosity of the liquid feldspars near their solidifying point as they approach the albite end of the series.

Any comparison of the grain of rocks, that is, the size of the constituent crystals, with a view to determining the physical conditions attending the solidification of the magma, must be based in the first instance on a knowledge of the behavior of the various rock-making minerals under similar physical conditions, both separately and in combination, that is, in solution with one another. The granularity of rocks is clearly a function of the chemical composition.

With respect to the homogeneity of the crystals separating from the liquid, it is observed that the great part of each crystal aggregation appears to be of one composition, but that in some cases a small proportion, probably less than 1 per cent, is different from the bulk of the feldspar, both in composition and habit. In one instance this small variant differed in composition but not in habit from the main mass of crystals.

In the first case it appears that crystallization began with feldspar richer in the anorthite molecule than the solution and developed cuboidal forms. These were prolonged into prismatic

bundles, the prisms having the composition of the main mass of crystals.

In the second case the small variant crystallized toward the end of the crystallization and contained more albite molecules than the main mass of feldspar crystals. It had the same habit as the other more calcic portion, and appears to have crystallized at the same time with it, the crystals with different optical properties being by the side of one another and not in zonal relation. Neither of the feldspars represents the end members of the series, An or Ab."

The Introduction to the volume by Becker, to whom the original plan of the work is largely due, will be read with much interest.

5. *The Tin Deposits of the Carolinas*; by J. H. PRATT and D. B. STERRETT. 64 pp. Raleigh, 1904. Bulletin No. 19 of the North Carolina Geol. Survey, J. A. Holmes, State Geologist.—The occurrence of tin in the country, and the southern states particularly, is mentioned in Bulletin No. 260 of the Geological Survey, noticed on page 70. This paper, by Pratt and Sterrett, appears from the North Carolina Geological Survey and takes up in detail the tin deposits of North and South Carolina. The first discovery of tin ore was made near Kings Mountain, North Carolina, in 1883, though but little progress was made until 1903, when the Ross mine at Gaffney, South Carolina, was discovered. During these twenty years, considerable prospecting has been done on the Carolina tin belt, so that this can now be traced quite definitely in a northeasterly direction from Gaffney, Cherokee county, South Carolina, across Gaston and Lincoln counties, North Carolina. Tin deposits also occur in Rockbridge county, Virginia.

A full account is given of the work which has been accomplished thus far, and a brief statement is added of the occurrence of tin in other parts of the country and abroad. At present, the practical work in the Carolina belt is limited to hydraulic mining in the alluvial gravels, the vein tin requiring different and more expensive treatment. Such deposits as those of the Ross mine are regarded as thoroughly remunerative, but in a large proportion of the alluvial deposits the yield of cassiterite is relatively small and this fact makes successful mining more problematical.

6. *Tubicolous Annelids of the Tribes Sabellides and Serpulides from the Pacific Ocean*; by KATHARINE J. BUSH, Ph.D. 8vo, 130 pp., 44 plates.—This admirable memoir forms part of volume xii of the reports of the Harriman Alaska Expedition. It includes a list of all known Pacific Ocean species of these groups and a very complete bibliography. The systematic portion includes full descriptions and illustrations of all the known species from California to Alaska. In the case of *Spirorbis* all the known species are reviewed from other regions also. Many of the illustrations are from photographs reproduced as helio-types. The northwest coast of America seems to be one of the

great headquarters of the Sabellidæ, for the species are unusually large, handsome, and numerous. Many new genera and species are described and the previously known genera are revised.

A. E. V.

7. *A Student's Text-Book of Zoology*, Vol. II; by ADAM SEDGWICK. London: Swan Sonnenschen & Co. New York: Macmillan Co. 705 pp., 333 cuts.—The second volume of this excellent text-book has been received. It includes the true Vertebrata and Cephalochorda. These are treated with unusual fullness both systematically and anatomically, and are well illustrated, though a large part of the cuts are the same as those used in the well known work of Claus. About fifty cuts are new. In the case of fishes the somewhat old classification of Gunther has been followed. Many later improvements in that group might well have been adopted. On the whole, it is the best text-book on the morphology of the Vertebrata now available.

A. E. V.

8. *A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut*; by HERBERT WILLIAM CONN. Bulletin No. 2, Connecticut State Geological and Natural History Survey. 69 pp., 34 pls., 1905.—This report deserves more than a passing notice because it is the first attempt yet made to enumerate and illustrate all the unicellular animals found in any locality in America. As implied by the title, the present report is but the beginning of an extensive work, in which it is aimed to eventually include a general study of all the Protozoa found in the State, with a consideration of their habits, evolution, geographical distribution, and their economic relation to the purity of drinking waters. The preliminary work for such a study must be the identification of the species, and to aid microscopists in recognizing the forms already found the present report is provided with 303 figures, all of which are from original drawings by the author from specimens collected in the State, and include every species which the author has thus far recognized in the region. No attempt has been made to give names to the new genera and new or unidentified species which are thus illustrated, such forms being designated merely as "new genus" and "sp. (?)" respectively. In the final report it is intended to furnish generic and specific diagnoses of all these forms, but the present work is provided with a brief description of the recognized genera only, specific descriptions being wholly omitted. There are admirably arranged keys to orders and genera. The figures are remarkably well drawn, and are printed in such a manner as to reflect great credit on the officers of the Survey, as well as on the author. The excellence of these plates is in striking contrast with the character of the illustrations published in the majority of State reports in recent years.

The value of this work will go far in justifying the inauguration of the newly established Geological and Natural History Survey of the State and forms a worthy leader of its series of zoological publications.

W. R. C.

9. *Études sur l'Instinct et les Mœurs des Insects*; by J.-H. FABRE. Souvenirs Entomologiques, 9^e Série, pp. 374. Paris.—This ninth volume of the author's very interesting accounts of the domestic life of insects describes in popular language some of his extensive observations on the habits and instincts of several species of spiders, a scorpion, gall insects, etc. W. R. C.

10. *The Rocky Mountain Goat*; by MADISON GRANT. Reprinted from the 9th Annual Report of the New York Zoological Society. New York, Office of the Society, 1905. 36 pp.—A well illustrated account of the systematic position, habits, and distribution of this little-known game animal, which is not strictly a goat, but the sole American representative of the *Rupicaprinae*, or mountain antelopes. W. R. C.

11. *A Catalogue of North American Diptera (or two-winged Flies)*; by J. M. ALDRICH. 680 pp. Washington, 1905. Smithsonian Miscellaneous Collections, No. 1444, part of volume xlvii.—The author states that this work is based upon the second edition of Osten Sacken's Catalogue of North America Diptera, published in 1878. It is by no means a reproduction of this, however, for the twenty-five years that have passed since Sacken's Catalogue have doubled the number of species and otherwise brought many changes; the careful labors of the author, aided by many gentlemen interested in the subject, have brought all this material together into a valuable and homogeneous volume.

12. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes*; by J. STANLEY GARDINER, M.A. Vol. II, Part IV, pp. 807-921, with plates lxvii-lxxxvii and text illustrations 127-139. Cambridge, 1905 (The University Press).—This continuation of the account of the collections made by the expedition of 1899-1900, repeatedly noticed in this Journal, contains the following reports: 1. The Alcyonaria of the Maldives, Part III, by Sydney J. Hickson. 2. Marine Crustaceans, XIV, Paguridae, by Major Alcock. 3. Hydroids, by L. A. Borradaile. 4. Notes on Parasites, by A. E. Shipley. 6. Marine Crustaceans, XV, Les Alpheidae, by H. Coutière.

Supplement I, pp. 923-1040, with plates lxxxviii-c and text-illustrations 140-153. This supplement contains the following reports: 1. Marine Crustaceans, XVI, Amphipoda, by A. O. Walker. 2. Madreporaria, III Fungida, IV Turbinolidæ, by J. Stanley Gardiner. 3. Scyphomedusae, by Edward T. Browne. 4. Coleoptera, by D. Sharp. 5. The Cephalopoda, by W. E. Hoyle. 6. Notes in the Collection of Copepoda, by R. Norris Wolfenden.

13. *The American Museum Journal*. Published quarterly by the American Museum of Natural History, New York City.—The second number of volume v, "the Brontosaurus number," contains an account of the mounted skeleton put on exhibition in February, 1905. It also describes the two bird groups recently completed in the museum, one of Flamingos, the other of the summer bird-life of San Joaquin valley, California; the former is particularly striking and successful.

14. *Cold Spring Harbor Monographs*. Published by the Brooklyn Institute of Arts and Sciences, March, 1905.—The following additional numbers have been issued.

IV. The Life History of *Casae* Bearers: 1, *Chlamys plicata*; by Ella Marion Briggs, 12 pp., with one plate and eleven text-figures.

V. The Mud Snail: *Nassa obsoleta*; by Abigail Camp Dimon, 48 pp., with two plates.

15. *Montana Agricultural College Science Studies; Botany*. Published quarterly by the College, Bozeman, Montana, 1905.—Numbers 1, 2 and 3 of volume i, 139 pp., issued together, contain the following papers:

I. A century of Botanical Exploration in Montana, 1805–1905, Collectors, Herbaria and Bibliography; by J. W. Blankinship.

II. Supplement to the Flora of Montana, additions and corrections; by J. W. Blankinship.

III. Common names of Montana Plants; by J. W. Blankinship and Hester F. Henshall. This is accompanied by an excellent colored plate of the pretty Bitter-root (*Lewisia rediviva*.)

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Vom Kilimandscharo zum Meru*; von C. UHLIG. *Zeitschrift für Erdkunde*, Berlin, Jahrg. 1904, No. 9 und 10.—This preliminary account of a journey of exploration in German East Africa contains much that is of interest. In reading the opening pages one cannot help reflecting how greatly the task of exploration in eastern Central Africa has been simplified in the last two or three years by the opening up of the Uganda Railway. The long and trying journey across the eastern desert region, which exhausted so much of strength, energy and resources before the real work began, is now performed in comparatively few hours. Thus our author leaves the coast on the 12th of September, and nine days later with his caravan is at Moschi on the lower slope of Kilimandjaro, ready to commence the ascent.

This he made from the eastern side without apparently any serious difficulty beyond the suffering entailed by the sudden change from the tropics to an arctic region. It will be recalled that Kilimandjaro has two summit peaks, a higher snow-capped one to the west called Kibo, and a lower one to the east called Kimawenzi or Mawenzi; these are separated by a deep saddle. Uhlig reached a height of about 19,500 feet on Kibo, but was unable to attain the highest point, which was about 200 feet more above him. He gives a number of interesting details concerning the snow and glacier formations accompanied by excellent photographs. Since the last ascent by Hans Meyer the amount of ice and snow appears to have distinctly increased. One striking feature was the occurrence along the snow slopes of long processions of weird and bizarre-shaped figures several feet high, similar to those observed, of much greater size, in the Andes, and to which the name of "nieve penitente" has been given from the suggestion which they offer of processions of white-

robed penitents. Uhlig remarks that those he saw much more resembled trains of white poodles, rabbits and the snow men made by children than penitents. He ascribes their formation to the ablation from insolation and the dryness of the air, though other factors must be sought to explain their regularity of arrangement, as they appear in two distinct lines, one up and down the slope, the other at right angles, i. e. along contour lines. The mention of this arrangement by Uhlig suggests that perhaps cracking of the hardened snow into such systems, combined with the agencies mentioned above, may explain the phenomenon.

He also made a second ascent of Kibo from the south into the glacier zone and discovered a new one, not previously mapped, to which the name of Richter glacier is given. A fine photograph of Kibo from the south shows a great snow-covered dome with long glacial tongues reaching down from it.

After this work on Kilimandjaro, Uhlig turned his attention to Meru, a great volcano which rises to the westward. Its height is about 15,200 feet. His first ascent was made from upper Aruscha on the south flank, at an elevation of about 4,500 feet. At 7,000 feet a girdle composed of dense masses of bamboos was encountered, which lasted to about 8,800 feet, and which required the greatest efforts to penetrate. It appears quite similar to the bamboo zone which Gregory encountered on Mt. Kenia, and which he found so difficult to surmount. Above this the mountain offered no especial difficulties aside from the extraordinary steepness of its slopes. Towards its upper limit the flora assumes the distinctly alpine character noted on the other great volcanoes of equatorial Africa. Some forms of vegetation, grasses, compositæ and *Arabis albida*, persist even to the top. No snow was found on Meru, its summit falling over 2,000 feet short of the snow-line on the neighboring Kilimandjaro. Nor were any marks of a former period of glaciation visible, although on Kilimandjaro, according to Meyer, the glaciation once extended some 3,000 feet lower than at present, and Gregory found evidences of much more extended glaciation on Kenia than it now shows. It is possible, however, that Meru may have had small hanging glaciers.

At the summit Uhlig found himself on the edge of a vast crater, whose precipitous walls fell beneath him, over 4,000 feet to the bottom. The highest point, on the opposite wall, he attempted in a second ascent from the northeast, but was unable to attain.

Meru is a concentric crater which shows several periods of volcanic activity. There is an outward somma with broad opening to the east. Within this and close to it is an inner somma with a narrow opening to the west through it and the outer one. Within these is the deep caldera mentioned above with relatively level surface, on the south side of which and near the encircling wall, rises an ash cone which Uhlig believes to have very recently been in an active condition. The caldera is about one and a half miles broad.

Mügge, who studied the rock specimens brought back by Fischer* from his journeys in equatorial Africa, found the sam-

* Neues Jahrb. für Min., Beil. Bd. iv.

ples collected near the base of Meru to be of tephrite, leading to the suspicion that the volcano was built up of extrusive magmas of alkalic nature. This was fully confirmed by the material collected by Uhlig, the preliminary study showing it to consist of varieties of the phonolite-tephrite family. There is thus added another instance to confirm the highly alkalic character of the East African petrographic province, whose nature and extent through the studies of Hyland, Gregory, Prior, Lacroix and others, we are now beginning to appreciate. Now that the way has been opened into eastern equatorial Africa, we may expect that detailed studies of the region, such as Uhlig has been making in the Kilimandjaro region, will furnish in geography, in geology and in other fields of science, results of great importance and interest.

L. V. P.

2. *Glacial Studies in the Canadian Rockies and Selkirks.*—

A paper upon the above subject, by W. H. SCHERZER, is contained in Part 4, Vol. II, of the Quarterly Issue of the Smithsonian Miscellaneous Collections. This gives an account of the results obtained in connection with the Smithsonian Expedition of 1904. It is made particularly interesting by a series of excellent illustrations reproduced from photographs. Many of the details of glacial structure are particularly well shown; as, for example, the Forbes "dirt bands," the "dirt stripes," the stratification and shearing exhibited in the glacial front, also the various forms of moraines under many different conditions.

3. *The Solar Observatory of the Carnegie Institution of Washington*; by GEORGE E. HALE. 22 pp. with 5 plates. Contributions from the Solar Observatory, Mt. Wilson, California, No. 2.—This second contribution from the Mt. Wilson Solar Observatory (see p. 473 of the June number) details the special objects aimed at in its construction and the particular lines of work which it is proposed to carry through. An account is given also regarding the erection of the Snow telescope, sent out by the University of Chicago, and also the progress made in the construction of other buildings. The present staff of the Observatory is as follows: Director, George E. Hale; Astronomer and Superintendent of Instrument Construction, G. W. Ritchey; and Assistants, Ferdinand Ellermann and Walter S. Adams.

4. *United States Naval Observatory, Rear-Admiral Colby M. Chester, U. S. N., Superintendent. Second series. Vol. IV, Appendix IV. The present status of the Use of Standard Time*; by EDWARD E. HAYDEN, Lieut. Commander, U. S. N. 28 pp. Washington, 1905.—This paper explains the use of "standard time" and shows the remarkable extension of this system over the world.

5. *Publications of West Hendon House Observatory, Sunderland. No. III, 1905. Pp. xi, 122, with 9 plates.*—This volume contains the results of an extended series of observations by Mr. T. W. Backhouse, upon certain variable stars, made during the years 1866-1904.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. X.—*On the Mechanical Equivalent of the Heat Vaporization of Water*; by R. H. HOUGH.

THE object of this investigation is the development of a method for the determination of the mechanical equivalent of the heat of vaporization of water directly in ergs: i. e., of a method not involving the use of the calorie.

This equivalent, which will be designated in what follows by L , is usually expressed in terms of the calorie varying from 536 C. to 540 C., depending on the particular calorie taken as the unit and the particular method pursued.

Regnault's is the only classic determination. He defined the calorie as the amount of heat to raise a kilogram of water from 0° to 1° , and worked out the following formula:

$$L = 606.5 - 0.695t - 0.00002t^2 - 0.0000003t^3$$

At standard pressure this gives the value 536.5, which is generally used by physicists, notably by Joly in the reduction of his determinations with the steam calorimeter. In close agreement with this value is the 536.2 of Berthelot, whose method was much less complicated. The empirical formula of Griffith:*

$$L = 596.73 - 0.601t$$

gives the value 536.63 in terms of the calorie from $14^{\circ}.5$ to $15^{\circ}.5$ centigrade. This agreement is only apparent, and a more just value of L is obtained by following Callendar,† who estimated L from the observations of Joly and Barnes. Joly‡

* Griffith, Phil. Trans. A., 1895, p. 261.

† Callendar, Proc. Roy. Soc., lxxvii, 1900.

‡ Joly, Proc. Roy. Soc., xlvii, 1889.

determined the mean specific heat of water from 12° to 100° in terms of the calorie at 20° using the following relation :

$$wL = Ws(t_1 - t_2)$$

observing w , W , t_1 , and t_2 , and taking Regnault's value of L , 536.5. Callendar substitutes in this relation Joly's observations of w , W , t_1 , and t_2 , and Barnes'* determination of the mean specific heat of water from 12° to 100° in terms of the calorie at 20° and solves for L . This gives the value of 540.2 in terms of the calorie at 20°. Callendar prefers this value to that of Regnault and uses it in his work on the properties of steam. It is probable that even this value is low, since Barnes'† values for the specific heats of water from 40° to 100° are almost parallel to but much lower than those of Regnault. There is much uncertainty as to the value of L in calories.

There is as yet no absolute determination of L in ergs. It may be expressed in ergs, however, as the product of L in calories into the mechanical equivalent of heat. Using 540.2 as the most probable value of L in calories at 20° and 4.184×10^7 as the most probable value of the mechanical equivalent at 20°, this being an average of the values due to Barnes, Rowland, Griffith, Schuster, and Moorby, gives 2.26×10^{10} against 2.24×10^{10} from Regnault's value.

The sources of error for this value are many. It can not be stated that the mechanical equivalent of the heat of vaporization of water is known with certainty to one per cent.

In any method of calorimetry involving the use of the calorie, no greater degree of accuracy can be attained than that of the calorie itself. But the determination of the value of C involves the use of the thermometer and all the errors incident to the measurement of temperature. That these are greater and more varied than is commonly supposed, and can only be corrected for by the exercise of the greatest care and skill, is definitely shown by Rowland‡ in his work on thermometry. He sees visions of careful, painstaking observers conscientiously reading with telescope and micrometer eye-piece to the thousandth part of a degree, unconscious of the fact that variations due to internal and external pressure, apparent friction and previous history, to say nothing of those due to the sectional calibration and the fundamental points, are many times as great as the usual errors of parallax and estimation.

Griffith,§ who is not so caustic though quite as vigorous, says: "The difficulties with regard to the measurement of temperature are not peculiar to the electrical method of inves-

* Brit. Assoc. Rep., 1889.

† Phil. Trans. A., 1902, vol. cxvii.

‡ Rowland, Proc. Am. Acad. of Arts and Sciences, vol. xv.

§ Griffith, Phil. Trans., 1898.

tigation, and therefore I need not dwell upon them. I would, however, venture to add my expressions of astonishment to those of Rowland, that so many enquirers attach so little importance to this point: many investigators, whose methods have otherwise been of a high order of accuracy, having satisfied themselves with the mercurial thermometer as a standard." Rowland* rejects, as having no weight, previous determinations in which the thermometer readings were not reduced to the air scale. As to the difficulty of this reduction, and to the general uncertainty of the apparent readings of the ordinary thermometer, a very instructive object lesson is to be found in an article by Cole and Durgan,† entitled "An Example in Thermometry."

It is the record of a systematic calibration of a Gerhardt thermometer, made in a concise and thorough manner. The mere statement of the corrections made, the record of the observations, and the results of the calculations, stated as briefly as consistency with clearness would permit, occupy twenty pages. In his determination of the mechanical equivalent of heat, Rowland made the most involved and elaborate corrections on his thermometer readings, and only brought his results and those of Joule into agreement by making the same kind of corrections for the latter's thermometers. Without raising the question of the soundness of such corrections, it is evident that a method for the determination of any fundamental heat constant independent of them is desirable if only to serve as a check: for the only way to minimize their effect is to extend the range of temperature, which is sure to increase the errors due to radiation, conduction and the calorimeter constant.

The error due to the latter constant need not be large, provided only that the water equivalent of the calorimeter be small compared with that of the substance under observation, and this can usually be accomplished without much difficulty.

The error due to the water vapor in the steam is only present in methods of steam calorimetry and is almost entirely eliminated by the differential method.

The errors due to radiation, convection and conduction are more serious. Reynolds‡ remarks on Joule's determination "that notwithstanding the greater facilities enjoyed by subsequent observers owing to the progress of physical appliances, the inherent difficulties remained: the losses from conduction and radiation could only be minimized by restricting the range of temperature and this ensured thermometric difficulties, par-

* Rowland, *Proc. Am. Acad.*, vol. xv.

† Cole and Durgan, *Phys. Review*, vol. iv, 1896.

‡ Reynolds, *Phil. Mag.*, 1897.

ticularly with the air thermometer which does not admit of very close reading." In fact, so uncertain are the corrections for radiation and conduction, that Griffith* asserts as "the general principle on which he proposed to work, that of eliminating the effects of radiation, conduction, etc., rather than that of ascertaining the actual loss or gain due to such causes." He eliminates these effects by maintaining the walls of the chamber enclosing his calorimeter at a constant temperature and gradually raising the temperature of the calorimeter from some point below to some point above that of the jacket, such that the gain and loss by the calorimeter are equal. This he calls the null point and determines it experimentally. The correction for convection by this method is doubtful. Rowland, who also bounces the losses due to radiation, convection and conduction, estimates the loss by convection to be more than 75 per cent of the total losses from these causes. He likewise corrects empirically. Obviously a better plan would be to eliminate not only the effects but the cause of these errors by maintaining the calorimeter, the jacket and the intervening medium at the same constant temperature, if a method admitting of such a process is possible. In fact, the principle of elimination of source of error is fundamental to all physical measurements since minimization and correction formulæ can never be more than a series of successive approximations.

The grounds then for a new method of determining L are: (a) the absence of any authoritative determination; (b) the absence of any absolute method; (c) the inherent sources of error in the present indirect methods. These are sufficient but there are weightier considerations: i. e. the advantages resulting from the use of L as the primary heat unit. Much can be said in favor of L instead of C as the primary heat unit, especially since the development of steam calorimetry by Bunsen and Joly.

The substance under calorimetric observation may be in a thermo-dynamic or in a thermo-static condition. The temperature may be changing, or it may be constant. In the first case the thermometer should be accurate, delicate and sensitive. That is to say, that not only should all corrections to reduce its readings to the air scale be definitely known, but it should respond to small variations of temperature in a readable degree and respond quickly. In this case the readings must be taken rapidly and are necessarily limited in number. In the second case the thermometer should be accurate and delicate but not necessarily sensitive to a higher degree. The readings may be taken more leisurely, with greater precision, and are only

* Griffith, Phil. Trans., 1893.

limited in number by expediency. It is apparent that methods necessitating observations of the first class are, other things being equal, inferior to those involving readings of the second class only. The determinations of Regnault, Joule, Rowland, Moorby, Griffith and Barnes all involve observations of the first class. In Joly's method of steam calorimetry, however, the temperature readings are made while the substance is in a state of thermal equilibrium which may be maintained almost indefinitely.* In this respect his method is unsurpassed. An absolute determination of L substituted for the Regnault value used by Joly would enhance the value of his work many fold. His differential method is unquestionably the best general method of calorimetry yet devised, the use of an uncertain constant being, as Joly himself pointed out, its weakest point.

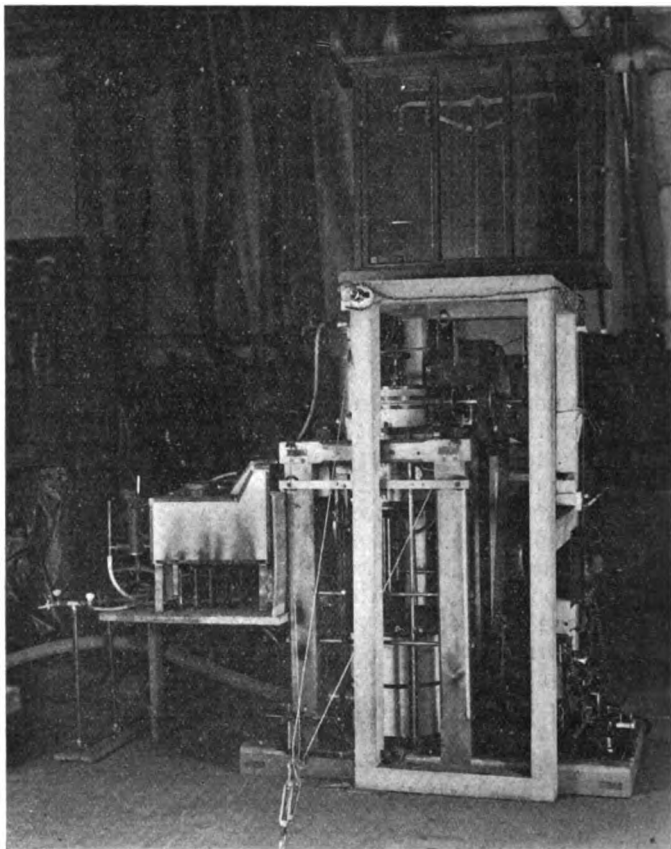
Barnes' curve for the heat capacity of water from 0° to 100° will never be changed much except, perhaps, by shifting the origin along the axis of specific heats. Rowland determined only a small portion of this curve, which from 10° to 20° is practically parallel to Barnes' but lower in value. Regnault determined the portion of the curve between 40° and 100° . It is also practically parallel to Barnes' but much higher. This indicates the presence of constant errors—but where? In this particular work the men are to be given almost equal weight. A constant error in Rowland's work, whose results agree among themselves most perfectly but for which he only claims an accuracy of two parts in a thousand, is hard to locate. It is possibly due to the sensitiveness of his thermometers not being great enough for observations on a substance in a thermodynamic condition. Regnault's constant error is likely due to several causes, including radiation, while Barnes' is possibly due to the position of his thermometers, as this is a source of error common to all continuous methods and very hard to eliminate or to correct for. In some preliminary work on the ratio of L to C , an attempt was made to develop a continuous method of steam calorimetry. It was abandoned for a time at least because the results, while agreeing very well among themselves, were found to be a function of the position of the thermometers placed in the ingoing and outgoing water. It would not be safe then to decide which of these curves, agreeing so well in all but their positions, is nearest to the true one. The substitution of the true value of the heat of vaporization of water in Joly's determination of the mean specific heat of water from 12° to 100° in terms of the calorie at 20° , would give a value by which Barnes' curve could be shifted. In this way much of the work of previous investigators in calorimetry

* Joly, *Proc. Roy. Soc.*, vol. xlvii, 1889.

would be enhanced in value. Hence an absolute determination of the mechanical equivalent of the heat of vaporization of water is a thing to be desired in itself.

The present method aims at the elimination of the errors due to thermometry, the calorimeter constant, the water vapor in the steam, radiation and convection, and a rigorous correc-

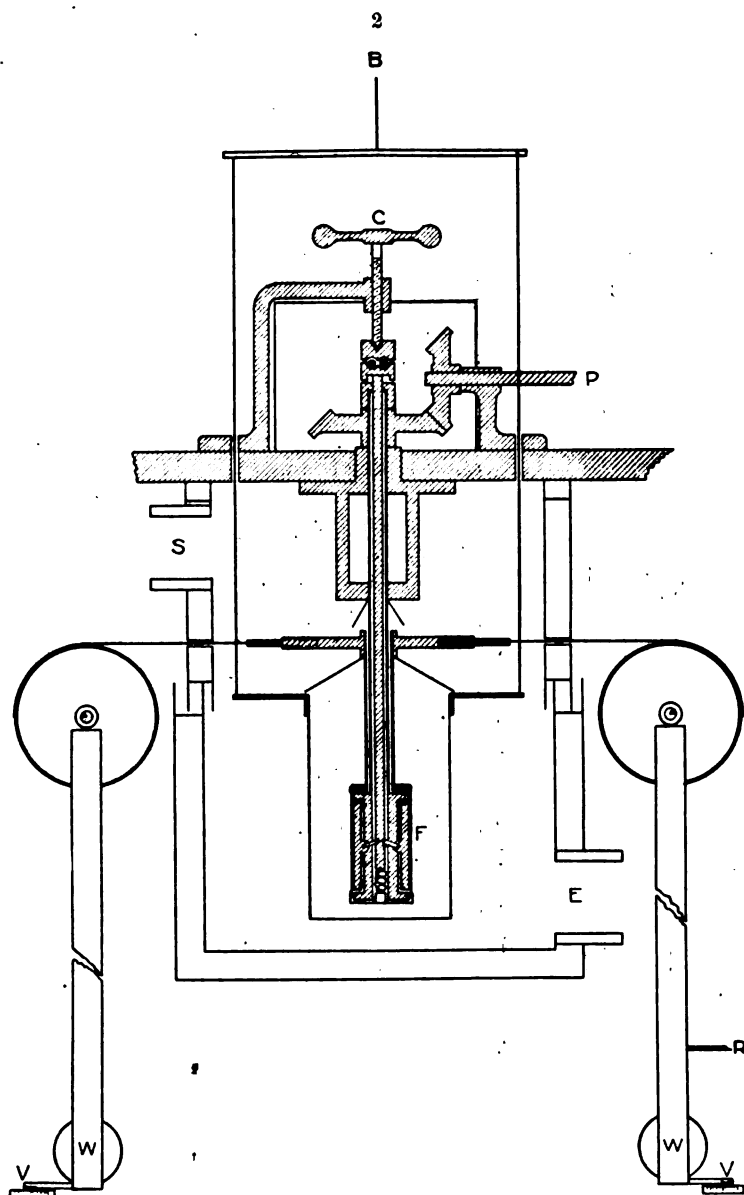
. 1



tion for conduction. The devices used to attain these ends will be described in detail followed by a discussion of the principles involved.

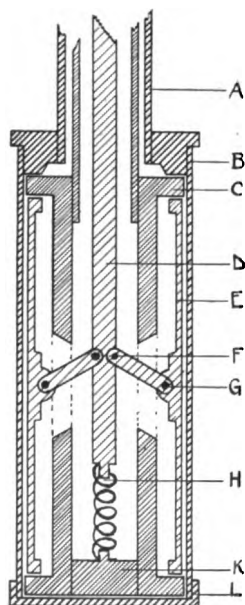
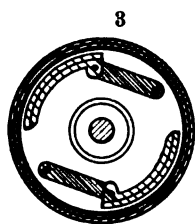
The general plan of the machine and the relation of its parts is best shown by the photograph (fig. 1) and the conventional diagrams (figs. 2 and 3). It consists essentially of (a) a vertical

shaft to which power is supplied : (b) a friction brake of peculiar design to convert the mechanical energy into heat : (c) a controlling device to maintain a convenient constant load : (d)



a cup suspended from the arm of a balance to hold the water to be evaporated: (e) two bent levers to balance the friction against gravity: (f) a recording device to plot the variation of the mechanical force with the number of revolutions: (g) a counter to register the number of revolutions: (h) a clutch for throwing the recorder and the counter in or out of gear at will: (i) a double-walled jacket: (j) a shield between the cup and the jacket to prevent radiation: (k) a steam supply to furnish the steam bath.

The vertical shaft consists of a hollow steel tube turned and fitted to accurately bored brass boxings. Power is communicated to this through the bevel gearing at the top from the horizontal shaft which is driven by a motor. To this horizontal



shaft is geared, through the clutch by which they are operated, the recorder and the counter. The counter is a Veeder and gives excellent service. The recorder consists simply of a horizontal drum whose angular velocity is a linear function of that of the brake. This carries the paper vertically under the marker. The marker is moved horizontally by means of the familiar device for parallel motion invented by Watt. The parts of this registering apparatus are very light and accurately centered on hardened steel cone bearings. They communicate directly with one of the bent levers so that the position of the marker at any instant is a linear function of the mechanical force. The marker is not in continuous contact with the paper, but only for an instant at regular intervals when struck by a bar which is actuated by a cam geared directly to the drum. The bent levers consist of accurately turned cast-iron pulleys with hardened steel knife edges bearing on hardened steel surfaces. Attached to these pulleys are pendulum bars and bobs. Flexible steel tapes with swivel joints transmit the moment from the disk of the friction brake to the pulleys of the bent levers. The friction brake consists of a bobbin threaded to the vertical shaft and rotating with it. Two rubbers, quadrant sections of a turned steel tube,

are hinged to the bobbin by means of a double joint which permits radial motion. A toggle joint, operated by a rod inside the vertical shaft, connects the two rubbers diametrically through an opening in the bobbin. This rod is forced upwards by means of a strong spiral spring in the bottom of the bobbin, and draws the rubbers in toward the center at the same time. When pressed down by the controlling device at the top, it forces the rubbers out radially. Surrounding the rubbers and accurately turned to fit them, is a cylinder supporting a torsion disk at the top. As the shaft rotates the rubbers move with it, and on account of the friction drag the cylinder and the torsion disk at the top with them. This motion is communicated by the tapes to the pulleys of the bent levers and the pendulums are displaced until their moment is equal to that of the friction. The double hinged joints are the important feature of this device. They permit the rubbers to seat themselves perfectly in the cylinder and the resulting friction is very uniform. In fact, the small periods of its variations are so short compared to that of the long bent levers that they are completely integrated by these levers, the record being almost a straight line. The controlling device consists of a hand screw to force down the rod operating the toggle joint. This pressure is transmitted through the ball-bearing since the rod is rotating with the shaft.

The manipulation of the machine is quite simple. A steam bath is allowed to flow through the chamber from the boilers throughout the experiment, maintaining all parts inside the shield at the temperature of the bath. The motor is started and the load is gradually increased by the control to the desired constant. When the water is evaporating freely and the thermal conditions have been maintained constant for some time, the weights are adjusted a little light and, as the water in the cup evaporates and the pointer comes to the zero, the clutch is operated throwing the counter and the recorder in gear, the weights and the counter having been observed and recorded. After any convenient period the weights are again adjusted a little light and the clutch again operated just as the pointer comes to zero, the counter and the weights being observed and recorded.

The calculation of the mass of the water evaporated is made in the usual way, but that of the mechanical energy may need a word of explanation. Since the ordinates and the abscissas of this curve are linear functions of the friction and the number of the revolutions of the rubbers, the following relations hold:

$$W = \int_0^s f \cdot ds$$

$$= C \int_0^x y \cdot dx$$

$$= C \cdot A$$

but

$$A = X \bar{y}$$

$$= C_1 S \bar{y}$$

where \bar{y} = average ordinate

$$S = n \cdot 2\pi r$$

where n = no. of revolutions

r = radius of disk

$$y = \frac{w_1}{w_2} l$$

where w_2 = total weight of paper

w_1 = weight of A

l = width of paper

$$c_1 = g \cdot G$$

where g = acc. due to gravity

G = mass in grams to

displace marker 1^{cm}.

$$W = \frac{w_1}{w_2} l \cdot g \cdot G \cdot n \cdot 2\pi r.$$

The constant G is determined by empirical calibration, for which four steps are necessary: the calibration of the scale of one of the pendulums in grams per centimeter by suspending weights in a pan from the pulley: the adjustment of the mass of the other pendulum bob to the same grams per centimeter: the adjustment of either tape until any deflection of the disk gives the same displacement on both scales: the calibration of the marker in terms of these scales. This determines G .

A second set of observations is taken using a second cylinder of different conductivity capacity from that of the first and L is determined from the following relation:

$$W = u_1 + u_2 + R$$

where u_1 = heat in ergs to the rubbers

u_2 = heat in ergs to water

R = heat in ergs radiated

if the temperature of the shield approaches that of the cylinder

$$R \doteq 0 \quad \text{and}$$

$$W = u_1 + u_2$$

$$\text{but } u_2 = (m + m')L$$

where m = apparent loss of water in the cup

m' = water deposited on cup due to water vapor in steam

and if $m \doteq 0$

$$u_2 = mL$$

$$W = u_1 + mL.$$

Let

$$\begin{aligned} W &= u_1 + u_2 \quad \text{for the first cylinder} \\ W' &= u'_1 + u'_2 \quad \text{for the second cylinder} \\ &\text{and} \quad u_1 = m L \\ &\quad \quad \quad u'_1 = m' L \end{aligned}$$

$$\frac{u_1}{u'_1} = \frac{W - m L}{W' - m' L}.$$

$$\text{But} \quad du_1 = \frac{k_1 A_1}{l_1} (T_1 - T_2) dt$$

$$du_2 = \frac{k_2 A_2}{l_2} (T_1 - T_2) dt$$

$$du'_1 = \frac{k'_1 A'_1}{l'_1} (T'_1 - T'_2) dt$$

$$du'_2 = \frac{k'_2 A'_2}{l'_2} (T'_1 - T'_2) dt$$

where k = specific conductivity
 A = cross section of conductor
 l = length of conductor
 T = temperature
 t = time

integrating

$$u_1 = \frac{k_1 A_1}{l_1} \int_0^t (T_1 - T_2) dt$$

$$u_2 = \frac{k_2 A_2}{l_2} \int_0^t (T_1 - T_2) dt$$

$$u'_1 = \frac{k'_1 A'_1}{l'_1} \int_0^{t'} (T'_1 - T'_2) dt$$

$$u'_2 = \frac{k'_2 A'_2}{l'_2} \int_0^{t'} (T'_1 - T'_2) dt$$

and

$$\frac{u_1}{u'_1} = \frac{\int_0^t (T_1 - T_2) dt}{\int_0^{t'} (T'_1 - T'_2) dt}$$

$$\frac{u_2}{u'_2} = \frac{\frac{k_2 A_2}{l_2} \int_0^t (T_1 - T_2) dt}{\frac{k'_2 A'_2}{l'_2} \int_0^{t'} (T'_1 - T'_2) dt}$$

$$= R \cdot \frac{\int_0^t (T_1 - T_2) dt}{\int_0^t (T'_1 - T'_2) dt}$$

where R = ratio of the conductivity capacities of the two cylinders.

$$\begin{aligned} \frac{u_1}{u'_1} &= \frac{u_1 I}{u'_1 R} \\ &= \frac{m I}{m' R} \end{aligned}$$

$$\frac{m}{m' R} = \frac{W - mL}{W' - m' L}$$

$$L = \frac{W}{m} + \frac{1}{R - 1} \left(\frac{W}{m} - \frac{W'}{m'} \right)$$

In the second term of the right hand member the two factors always have opposite signs. The correction is therefore a negative quantity. By reducing the conductivity capacity of the rubbers and increasing that of the cylinder, this correction is reduced to a minimum. Only the ratio of the conductivity capacities is demanded by this formula, not the specific conductivities. This ratio is determined by the method of cooling.

The advantages of this method are: the measurement of all quantities involved to a high degree of accuracy, depending only on the skill of the mechanician: the elimination of all errors due to thermometry, the calorimeter constant, the water vapor in the steam, radiation and convection: the minimization and rigorous correction for conduction.

Preliminary tests of the most rigorous type show that all the factors that enter into this result are entirely within control. A long series of observations are to be made during the coming year, from which it is confidently expected that a value accurate to at least one part in a thousand will be obtained.

University of Pennsylvania.

ART. XI.—*The Phosphorescence of Zinc Sulphide through the Influence of Condensed Gases obtained by Heating Rare-Earth Minerals*; by CHARLES BASKERVILLE and L. B. LOCKHART.

HELIUM has been shown to be a product of the disintegration of radium emanations; it is also obtained from minerals which contain thorium and uranium. It has been shown by Afanassiew, Mme. Curie, Crookes, Strutt, Hoffman, Baskerville, and Boltwood that minerals containing these elements are radio-active.

It seemed to be of interest to ignite these minerals and condense the gases given off and note their effect upon phosphorescent zinc sulphide. The method of procedure was essentially that described in the preceding paper, except that the pulverized mineral was placed in the closed tube of hard glass instead of a radium preparation. Screens of Sidot's blende were prepared in strips for the purpose. The glowing of the screen was assumed to indicate the condensation of the emanation.

No final conclusion could be drawn from the experiments, which were distinctly qualitative. It appeared, however, that those minerals which offer the richest sources of helium gave the greatest amount of emanation. Most of the minerals were obtained by purchase, but we are indebted to Dr. Geo. F. Kunz for some of them, to Dr. H. S. Miner, of the Welsbach Lighting Co., for others, and to the Nernst Lamp Co., Pittsburgh, Pa., for still others.

In addition to the minerals we made some experiments with uranium compounds*, commercial thorium oxide, and the fractions of that element obtained in our laboratory.

The list of minerals, and observations follow:

Mineral.	Locality.	Result.
Aeschynite	Hitterö, Norway	Fair glow
Allanite (orthite)	Amherst Co., Virginia	No glow
Allanite	Amherst Co., Virginia	No glow
Annerödite	Norway	No glow
Auerlite	Henderson, N. C.	Fair glow
Bastnäsite	Manitou Springs, Col.	No glow
Brookite	Arkansas	No glow
Carnotite	La Salle Creek, Mont. Co., Colorado	Fine glow
Carnotite	Utah	No glow
Catapleiite	Brevig, Norway	No glow
Cerite	Bastnäs, Sweden	Fair glow
Cleveite	Moss, Norway	Fine glow
Columbite	Amelia Co., Virginia	No glow
Cryptolite	Bluffton, Texas	Faint glow
with Fergusonite	(Llano)	

* For which we are indebted to Dr. S. A. Tucker, Columbia University.

Mineral.	Locality.	Result.	
Cryptolite	S. Co., Texas	No glow	
Euxenite	Spangereid, Norway	Fair glow	
Euxenite	Arendal, Norway	Good glow	
Fergusonite	Ytterby, Sweden	Fine glow	
Gadolinite	Fahlun, Sweden	No glow	
Gummite	Mitchell Co., N. C.	No glow	
Hjelmite	Karapfvet	No glow	
Monazite sand	Brazil, S. A.	Fair glow	
Monazite	Norway	Medium	
Monazite sand	Mitchell Co., N. C.	Very faint glow	
Mixite	Joachimsthal, Bohemia	No glow	
Orangite	Norway	Medium	
Orthite	Arendal, Norway	No glow	
Pitchblende (Uraninite)		Medium glow (below fair)	
Pechurane	Bohemia	Strong glow	
Samarskite	Mitchell Co., N. C.	Fine glow	
Steenstrupine	Urals	No glow	
Thorite	Langesund, Norway	Fair glow	
Thorite (Orangite)	Brevig, Norway	Fair glow	
Thorogummite	Bluffton, Llano Co., Tex.	No glow	
Tritomite	Brevig, Norway	No glow	
Tyrite	Tromsø, Norway	No glow	
Uraninite	North Carolina	Fine glow	
Uraninite	Joachimsthal, Bohemia	Very faint glow	
Uranite	(rare)	No glow	
Uranophane	Spruce Pine, Mitchell Co., N. C.	Fair glow	
Xenotime	Hitterö, Norway	Faint	
Yttrio-tantalite	Ytterby, Sweden	No glow	
Zeunerite	S. B., Germany	No glow	
Substance.	Prepared by	Result.	Remarks.
Uranium carbide	Tucker	No glow	Not expected from our knowl- edge of the activ- ity of uranium.
Uranium oxide	Tucker	No glow	
Uranium nitrate	Purchased	No glow	
Thorium-X	Miner. From 100 gals. wash-water	Fair glow	
Thorium oxide	Same as for Welsbach burners	Fair glow	Slight glow with tiffanyites. No glow with solid willemite.
Berzelium* oxide	Irwin. Monazite sand	No glow	No glow with tiffanyites.
Thorium* oxide	Davis. Monazite sand	Fair glow	Slight glow with tiffanyites.
Carolinium* oxide	Skinner. Monazite sand	No glow	

* These preparations were made in our laboratory, University of North Carolina. All showed some but not the same radio-activity when tested by the electrical and photographic methods.

ART. XII.—*The Action of Radium Emanations on Minerals and Gems*;* by CHARLES BASKERVILLE and L. B. LOCKHART.

KUNZ and Baskerville† have made some interesting observations concerning the action on minerals and gems of radium compounds of the highest activity enclosed within glass, as well as of mixtures of weaker preparations with a limited number of minerals, especially diamonds, willemite and kunzite.‡ Rutherford used willemite most satisfactorily§ for demonstrating to a large audience the condensation of the emanations by means of liquid air. It was thought advisable to subject other minerals, found by Kunz and Baskerville to be fluorescent or phosphorescent, or both fluorescent and phosphorescent under the influence of ultra-violet light, to similar treatment. We wish to express our obligations to Dr. Geo. F. Kunz, who generously provided us with most of the minerals, all of which were authenticated.

The method of testing was as follows: About 0.25 gram of radium chloride, 7000 uranies|| strong, was placed in a hard glass tube 2^{mm} in diameter, sealed at one end. This was bound to a glass tube, provided with a stop-cock, which was bent so as to reach through one of the two holes in a rubber stopper to the bottom of a test-tube 2^{cm} wide and 15^{cm} deep. Through the other hole was passed a bent tube so that it just projected below the rubber. This tube was provided with a glass stop-cock and connected with an ordinary vacuum pump. The material upon which the action of the emanation was to be determined was placed in the wide test-tube. The tube was then dipped into liquid air contained in a suitable unsilvered Dewar bulb.

On opening the cock next to the pump while it was in operation a good vacuum was produced in the container tube. When this cock was closed, the radium chloride was heated to low redness. The cock between this and the test-tube was opened. The emanations were swept in and condensed. In every case the tube and contents were allowed to remain in the liquid air until they were assumed to have obtained an uniform temperature. All experiments were carried out in the dark and observations were made only after the eyes had become accustomed to the conditions.

* Read before the Washington Section of the American Chemical Society, April 6th, 1904.

† Science.

‡ Patent applied for.

§ Address before the American Association for the Advancement of Science, St. Louis, Mo., Meeting, Dec., 1903.

|| By an "uranie" is meant the radio-activity of metallic uranium, which is taken as the standard.

It was learned that tiffanyite diamonds are quite as sensitive to the action of the emanations as the phosphorescent zinc sulphide. We did not have enough diamonds to change for each experiment, so in each trial a strip of Sidot's blende screen was inserted. This served to show that the emanations had been condensed. We were much surprised to learn on frequent repetition of the experiment that kunzite, which is so responsive to radium, neither fluoresced nor phosphoresced when the emanations were condensed thereon. It is, therefore, responsive to the beta- and gamma-rays only.

Before giving the results of the observations, which follow in tabulated form, it may be well to relate the results obtained in several experiments, the bearing of which upon the question in mind is apparent.

The cooling of zinc sulphide to the temperature of liquid air does not cause it to glow, with or without vacuum. A good vacuum and a sudden releasing of the same does not cause zinc sulphide to glow. But warming it to ordinary temperature after removal from liquid air does cause it to glow brilliantly. Chlorophane and kunzite cooled in liquid air show no phosphorescence.

Action of emanations from radium chloride (7000 activity) on :

Mineral.	Locality.	Result.	Remarks.	With Ultra-Violet Light.
Wollastonite	Harrisville, Lewis Co., N. Y.	Slow to phosphoresce, faint	Tribo-luminescent	Phosphorescent
White wollastonite (with idocrase and pink garnet)	Morelos, Mexico	Glowing brilliantly	Loses glow in less than five minutes	Phosphorescent
Wollastonite	Franklin Tunnel, N. J.	Glowing brilliantly	Loses glow quickly	Phosphorescent
Pectolite	Havers, N. Y.	Nothing		Phosphorescent
Pectolite	Paterson, N. J.	Nothing		Phosphorescent
Pectolite	Guttenburg, N. J.	Nothing		Phosphorescent
Spodumene	Paris, Me.	Nothing		Nothing
Spodumene (hidenite)	Alexander Co., N. C.	Nothing		Nothing
Spodumene	U. G., Brazil, S. A.	Nothing		Nothing
Spodumene (kunzite)	Pala, Cal.	Very slight response		Phosphorescent
Willemite	Franklin, N. J.	Glowing well	Not so sensitive as zinc sulphide, or tiffanyite; glows with emanations from commercial thorium oxide	Fluorescent and phosphorescent.
Greenockite		Glowing strongly	Goes away quickly	Fluorescent
Hyalite	Yellowstone Park	Nothing		Fluorescent
Colemanite	Mono Lake	Nothing		Phosphorescent
Chlorophane	Amherst, Va.	Nothing		Phosphorescent
Tiffanyite	5 Dutch diamonds, 2¼ k.	Glowing very easily and brilliantly	Lasts several hours	Phosphorescence prolonged

ART. XIII.—*The Behavior of Typical Hydrous Bromides when Heated in an Atmosphere of Hydrogen Bromide;*
by J. LEHN KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxvii.]

IN former papers from this laboratory* the results obtained in the delhydration of certain hydrous chlorides in air and in an atmosphere of hydrogen chloride have been studied and compared. In the present paper the effects of treating typical hydrous bromides in air and in an atmosphere of hydrogen bromide are described.

Hydrous barium bromide has been taken as a type of hydrous salts which when heated in air lose their water without much further decomposition; hydrous magnesium bromide as typical of salts which lose part of their water without much further decomposition and the remainder with simultaneous evolution of hydrogen bromide; and hydrous aluminum bromide as typical of salts which lose their water only with simultaneous loss of hydrogen bromide.

The method of experimentation was very similar to that followed by Gooch and McClenahan† in their experiments with hydrous chlorides.

For these experiments two combustion tubes 30^{cm} in length and 2^{cm} in diameter, set horizontally side by side in a tubulated paraffine bath, served as heating chambers. Each tube was fitted with a thermometer. Portions of the hydrous bromides to be treated were weighed into porcelain boats. One of these boats was inserted in each tube about midway in the bath (heated to a regulated temperature) and below the bulb of the thermometer, so that the temperature to which the material in the boat was submitted might be indicated by the thermometer as accurately as possible. Through one tube was drawn slowly a current of air purified by sulphuric acid, and through the other was sent a slow current of purified hydrogen bromide, generated in a flask by the action of bromine on a heated solution of naphthalene and kerosene, and passed through a purifying apparatus consisting of a tower containing successive layers of red phosphorus and glass wool and a wash bottle charged with a saturated solution of hydrobromic acid. At the end of a definite period, the boat was withdrawn, placed in a desiccator for a suitable interval to cool, and weighed. The residue in the boat was dissolved in water, and the bromine was precipitated by silver nitrate, the silver bromide being weighed on asbestos. In this way it was

*Gooch and McClenahan, this Journal [4], xvii, 365. McClenahan, this Journal [4], xviii, 104.

† Loc. cit.

possible to determine the loss of water and hydrogen bromide from separate portions of the salt under examination, during definite intervals and at fixed temperatures, both in an atmosphere of hydrogen bromide and in air, and to find for each portion under examination what proportion of the total loss was hydrogen bromide and what was water. The tabular statements and the diagrams show the course of decomposition of the various salts for the temperatures indicated.

Hydrous Barium Bromide.

For the experiments with hydrous barium bromide, a well crystallized specimen was prepared by taking commercially pure barium carbonate, dissolving it in hydrochloric acid, precipitating by ammonium carbonate, washing the precipitate, dissolving in hydrobromic acid, and crystallizing and drying the crystals by pressing between filter papers. The analysis of different portions of this salt showed a definite composition, corresponding very closely to theory.

	Found.	Theory.
Ba	41.69%	41.60%
Br	48.05	47.95
2H ₂ O	10.26	10.45
	<hr/>	<hr/>
	100.00%	100.00%

The progress of the decomposition of this salt in air and in hydrogen bromide when submitted for a half hour to the temperatures indicated is shown in the accompanying table and diagram.

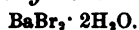
Here may be noted a gradual loss of water from 70° C. to 160° C., at which point the water is entirely expelled, without an appreciable loss of hydrogen bromide, either in air or hydrogen bromide, and that hydrogen bromide influences the process of dehydration in no marked way. There is nothing to show that any part of the water sustains a peculiar relation to the salt.

Hydrous Magnesium Bromide.

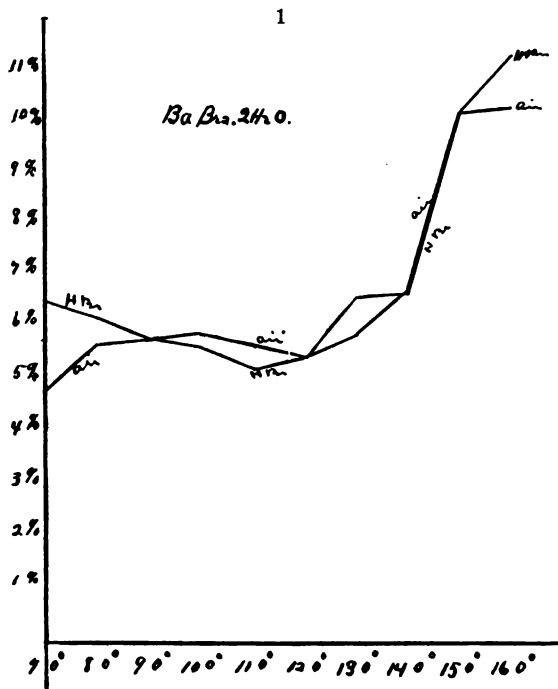
Similar experiments were performed with hydrous magnesium bromide, prepared by dissolving magnesium ribbon in hydrobromic acid and crystallizing the salt over sulphuric acid. The analysis of the salt gave a definite constitution corresponding fairly to theory.

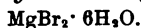
	Found.	Theory.
Mg	08.68	08.27
Br	54.61	54.69
6H ₂ O	36.71	37.04
	<hr/>	<hr/>
	100.00	100.00

Dehydration of Hydrous Barium Bromide.



Atmosphere.	Weight taken.	Loss on heating.		Bromine in residue.			Water evolved.	Time.	Temperature.
		gram.	gram. per cent.	gram.	per cent.	Variation from theory.			
1 { HBr	2377	0165	06.94	1130	47.56	-0.39	06.55	½	70°C.
1 { Air	2364	0107	04.52	1141	48.24	+0.29	04.81	½	70°C.
2 { HBr	2309	0147	06.36	1105	47.82	-0.13	06.23	½	80°C.
2 { Air	2247	0125	05.56	1082	48.16	+0.21	05.77	½	80°C.
3 { HBr	2299	0121	05.26	1115	48.49	+0.54	05.80	½	90°C.
3 { Air	2311	0127	05.49	1115	48.26	+0.31	05.80	½	90°C.
4 { HBr	2413	0121	05.01	1173	48.58	+0.63	05.64	½	100°C.
4 { Air	2416	0134	05.54	1167	48.33	+0.38	05.92	½	100°C.
5 { HBr	2399	0118	04.91	1157	48.26	+0.31	05.22	½	110°C.
5 { Air	2342	0128	05.50	1162	48.09	+0.14	05.64	½	110°C.
6 { HBr	2296	0115	05.00	1111	48.41	+0.46	05.46	½	120°C.
6 { Air	2287	0127	05.50	1095	47.91	-0.04	05.46	½	120°C.
7 { HBr	2501	0157	06.27	1208	48.32	+0.37	06.64	½	130°C.
7 { Air	2472	0135	05.46	1195	48.37	+0.42	05.88	½	130°C.
8 { HBr	2389	0198	06.58	1147	48.03	+0.08	06.66	½	140°C.
8 { Air	2304	0148	06.42	1113	48.31	+0.36	06.78	½	140°C.
9 { HBr	2491	0258	10.36	1190	47.78	+0.17	10.19	½	150°C.
9 { Air	2438	0251	10.29	1167	47.86	-0.09	10.20	½	150°C.
10 { HBr	2460	0269	10.93	1190	48.37	+0.42	11.35	½	160°C.
10 { Air	2416	0242	10.01	1166	48.26	+0.31	10.32	½	160°C.

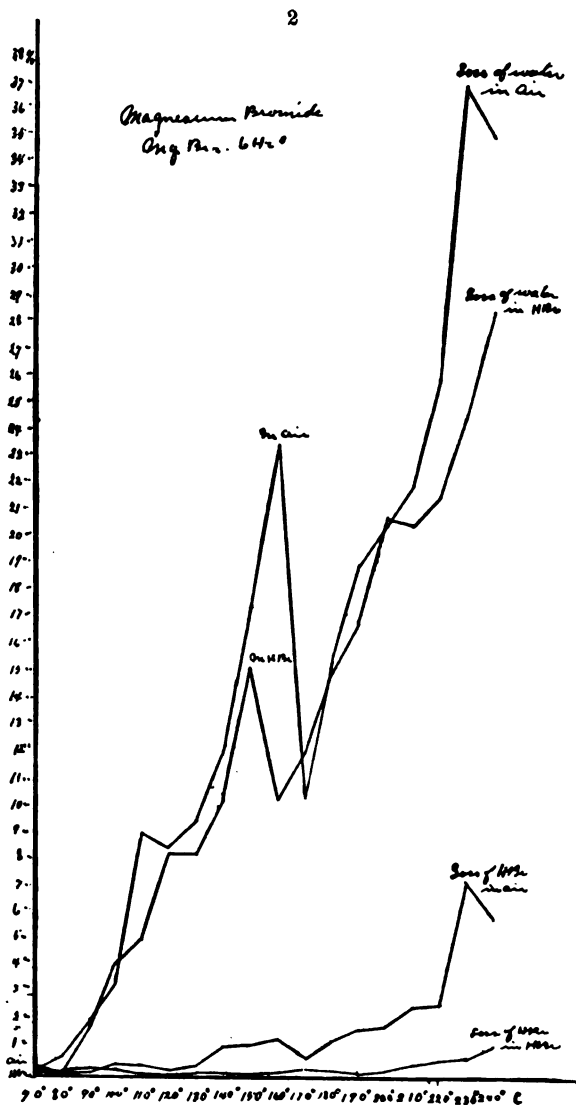


Dehydration of Hydrous Magnesium Bromide.

Atmosphere.	Weight taken.	Loss on heating.		Bromine in residue.		HBr lost.	Water lost.	Time.	Temperature.
		gram.	gram. per cent.	gram.	per cent.	per cent.	per cent.		
1	HBr	·2389	·0000	00·00	·1310	54·81	00·12	00·12	70° C.
	Air	·2400	·0000	00·00	·1319	54·98	00·29	00·29	
2	HBr	·1370	·0000	00·00	·0751	54·85	00·16	00·16	80°
	Air	·1380	·0012	00·86	·0752	54·55	00·14	00·72	
3	HBr	·1259	·0019	01·50	·0693	54·96	00·27	01·77	90°
	Air	·1482	·0023	01·95	·0813	54·87	00·18	02·13	
4	HBr	·1220	·0053	04·34	·0664	54·46	00·23	04·11	100°
	Air	·1448	·0048	03·31	·0797	55·07	00·38	03·69	
5	HBr	·1345	·0070	05·20	·0736	54·76	00·07	05·27	110°
	Air	·1384	·0103	07·44	·0752	54·33	00·36	07·80	
6	HBr	·1374	·0115	08·36	·0751	54·69	00·00	08·36	120°
	Air	·1353	·0120	08·86	·0737	54·50	00·19	08·67	
7	HBr	·1331	·0114	08·56	·0724	54·41	00·28	08·28	130°
	Air	·1317	·0128	09·71	·0714	54·28	00·41	09·30	
8	HBr	·1345	·0140	10·40	·0734	54·58	00·11	10·29	140°
	Air	·1369	·0183	13·37	·0733	53·59	01·11	12·26	
9	HBr	·1375	·0216	15·71	·0748	54·47	00·22	15·49	150°
	Air	·1358	·0251	18·48	·0727	53·58	01·12	17·36	
10	HBr	·1313	·0140	10·66	·0714	54·46	00·23	10·46	160°
	Air	·1311	·0324	24·71	·0698	53·26	01·44	23·27	
11	HBr	·1366	·0170	12·44	·0744	54·39	00·31	12·13	170°
	Air	·1379	·0159	11·53	·0744	54·00	00·69	10·84	
12	HBr	·1399	·0220	15·72	·0760	54·35	00·34	15·38	180°
	Air	·1358	·0232	17·08	·0723	53·27	01·43	15·65	
13	HBr	·1285	·0217	16·89	·0696	54·75	00·06	16·95	190°
	Air	·1324	·0275	20·77	·0702	53·06	01·65	19·12	
14	HBr	·1345	·0284	21·11	·0731	54·42	00·27	20·84	200°
	Air	·1382	·0312	22·57	·0730	52·87	01·84	20·73	
15	HBr	·1349	·0282	20·90	·0731	54·19	00·50	20·40	210°
	Air	·1350	·0331	24·51	·0704	52·20	02·51	22·00	
16	HBr	·1337	·0297	22·21	·0722	54·01	00·68	21·53	220°
	Air	·1320	·0379	28·71	·0686	52·03	02·69	26·02	
17	HBr	·1354	·0340	25·11	·0731	54·02	00·67	24·47	230°
	Air	·1373	·0606	44·13	·0649	47·43	07·35	36·78	
18	HBr	·1376	·0401	29·14	·0740	53·69	01·01	28·13	240°
	Air	·1360	·0555	40·80	·0665	48·93	05·80	35·00	

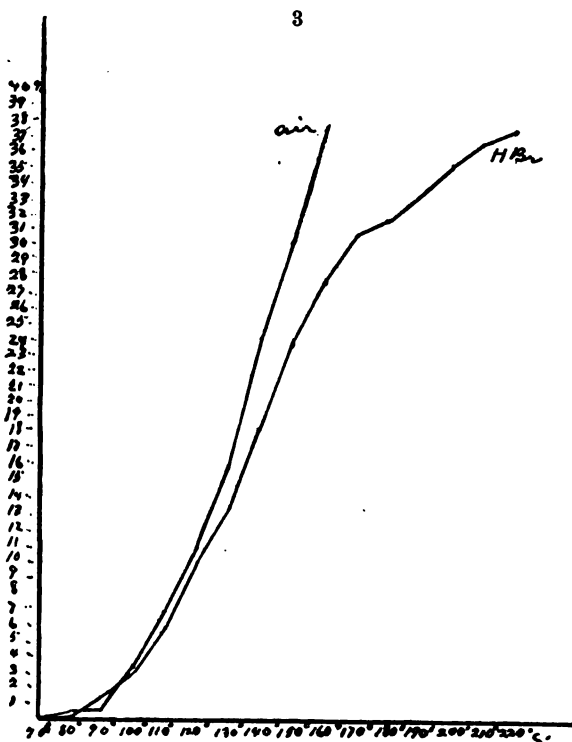
From these results it appears that approximately a third of the water may be removed from the hydrous magnesium bromide, submitted at once to the temperatures indicated, either in air or in an atmosphere of hydrogen bromide, without considerable simultaneous loss of hydrogen bromide from the salt, the trifling loss being somewhat less in the atmosphere of

hydrogen bromide than in air. Thereafter the loss of hydrogen bromide when the salt is heated in air increases generally with the temperature and is inhibited, as is the loss of water,



by the atmosphere of hydrogen bromide. It appears that about a third of the water of magnesium bromide bears a relation to the salt different from that of the remainder.

When submitted at once, without preliminary heating, to a temperature of 170° in air and 160° in hydrogen bromide, the hydrous salt melts and in the melted condition loses water less rapidly than the solid salt at a somewhat lower temperature. This is what makes the break in the curves which indicate the losses of water and hydrogen bromide. When the salt was heated successively, for intervals of a half hour, at temperatures varying by ten degrees, the progress of dehydration was more uniform, as is shown in the accompanying diagram, all the water being lost at 160° in air and 220° in hydrogen bromide, the inhibiting action of hydrogen bromide upon the dehydration being more marked as the temperature rises from the point at which the first third is lost.



Hydrous Aluminum Bromide.

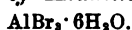
The hydrous aluminum bromide used was prepared by dissolving pure aluminum chloride in water, precipitated aluminum hydroxide by ammonium hydroxide, filtering off the aluminum hydroxide, and washing until free from impurities. This precipitate was then dissolved in hydrobromic acid, and

the solution thus formed allowed to crystallize by evaporation in vacuum over sulphuric acid: the crystals thus formed were of nearly normal constitution.

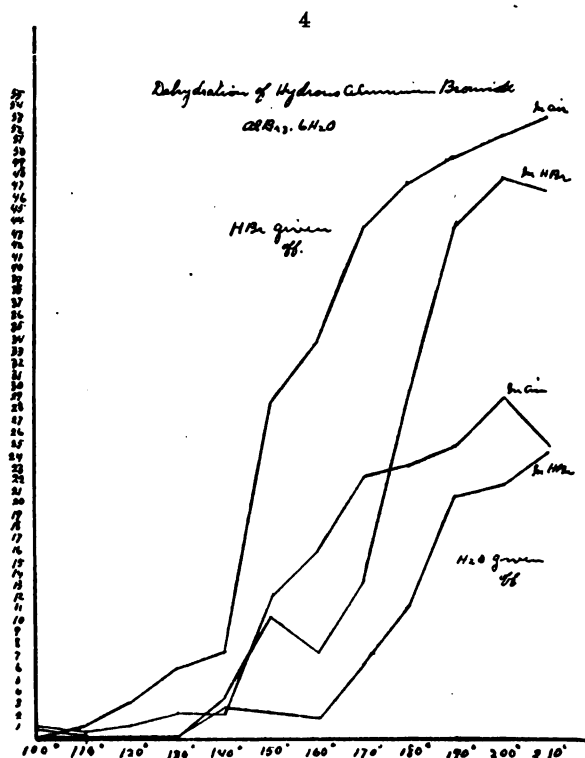
	Found.	Theory.
Al	07·25%	07·20%
Br ₂	63·90	63·95
6H ₂ O	28·85	28·85
	<hr/> 100·00	<hr/> 100·00

The course of dehydration of hydrous aluminum bromide in air and in an atmosphere of hydrogen bromide is shown in the accompanying table and diagram.

Dehydration of Aluminum Bromide.



Atmosphere.	Weight taken. gram.	Loss on heating.		Bromine in residue.		HBr lost.	Water lost.	Time. hrs.	Temperature.
		gram.	per cent.	gram.	per cent.	per cent.	per cent.		
1 { HBr	·1308	·0000	00·00	----	----	----	----	½	70° C.
1 { Air	·1308	·0000	00·00	----	----	----	----	½	
2 { HBr	·1394	·0000	00·00	----	----	----	----	½	80°
2 { Air	·1381	·0000	00·00	----	----	----	----	½	
3 { HBr	·1344	·0000	00·00	----	----	----	----	½	90°
3 { Air	·1360	·0000	00·00	----	----	----	----	½	
4 { HBr	·1317	·0008	00·60	·0831	63·13	00·83	00·23	½	100°
4 { Air	·1316	·0014	01·06	·0842	64·05	00·10	01·16	½	
5 { HBr	·1364	·0008	00·58	·0861	63·60	00·35	00·23	½	110°
5 { Air	·1378	·0024	01·74	·0865	62·83	01·13	00·61	½	
6 { HBr	·1381	·0008	00·57	·0878	63·62	00·33	00·24	½	120°
6 { Air	·1367	·0054	03·95	·0834	61·07	02·91	01·04	½	
7 { HBr	·1297	·0006	00·46	·0825	63·64	00·31	00·15	½	130°
7 { Air	·1318	·0106	08·04	·0767	58·24	05·78	02·26	½	
8 { HBr	·1379	·0011	00·79	·0831	60·32	03·67	02·89	½	140°
8 { Air	·1357	·0127	09·35	·0771	56·85	07·18	02·17	½	
9 { HBr	·1366	·0113	08·27	·0730	53·46	10·62	02·35	½	150°
9 { Air	·1355	·0549	40·51	·0485	35·84	28·46	12·05	½	
10 { HBr	·1308	·0121	09·25	·0740	56·57	07·43	01·82	½	160°
10 { Air	·1348	·0668	49·55	·0413	30·66	33·71	15·84	½	
11 { HBr	·1380	·0270	19·56	·0703	50·94	13·17	06·39	½	170°
11 { Air	·1390	·0919	66·11	·0281	20·72	43·77	22·34	½	
12 { HBr	·1378	·0561	40·71	·0477	34·65	29·67	11·04	½	180°
12 { Air	·1346	·0949	70·50	·0232	17·28	47·26	23·24	½	
13 { HBr	·1331	·0850	63·86	·0280	21·09	43·40	20·46	½	190°
13 { Air	·1307	·0976	74·67	·0193	14·80	49·72	24·95	½	
14 { HBr	·1362	·0938	68·87	·0232	17·08	47·46	21·41	½	200°
14 { Air	·1377	·1090	79·15	·0197	14·33	50·24	28·91	½	
15 { HBr	·1355	·0958	70·70	·0246	18·04	46·49	24·21	½	210°
15 { Air	·1345	·1040	77·32	·0158	11·76	52·85	24·47	½	

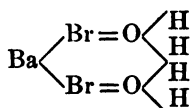


From these results it appears that, at 100° and higher temperatures, hydrous aluminum bromide loses water and hydrogen bromide simultaneously, both in air and in an atmosphere of hydrogen bromide; but that the loss of water, as well as of hydrogen bromide, from the salt is retarded by the atmosphere of hydrogen bromide. At the highest temperature recorded, 210° C. the salt still retained bromine. There is nothing to indicate that any part of the water possesses a different relation to the salt from that possessed by any other part of the water.

Discussion of Results.

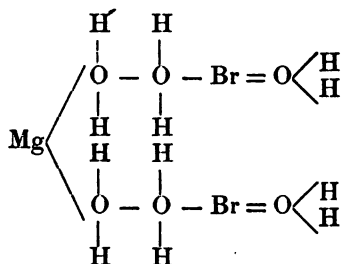
In correlating the phenomena noted, Cushman's hypothesis of inner and outer linkages of water relative to the molecular complex, upon the assumption of quadrivalent oxygen, seems applicable.

Thus the symbol



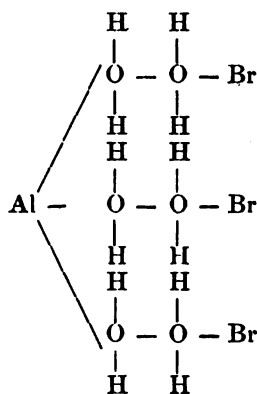
for hydrous barium bromide, showing two molecules of water externally attached, suggests the observed easy removal of all water without simultaneous loss of hydrogen bromide, and indicates, as was observed, that concentration of hydrogen bromide in the system is not likely to affect the course of dehydration.

The symbol



for hydrous magnesium bromide, in which two molecules of water are externally attached and four internally, shows why one-third of the water may be removed at a moderate temperature, without much loss of hydrogen bromide; why the remaining two-thirds of the water require a higher temperature for their removal with simultaneous evolution of hydrogen bromide; and why increase in the concentration of hydrogen bromide in the system retards both the loss of water and hydrogen bromide, after the first third of the water has been expelled.

The symbol



for hydrous aluminum bromide suggests the observed impossibility of evolving water without simultaneous loss of hydrogen bromide, the salt tending on continued heating to go over to the oxide. With a salt showing this constitution the natural effect of the concentration of hydrogen bromide in the system would be to retard the dehydration of the salt, as was observed.

So it appears that the phenomena of dehydration of the hydrous bromides under discussion admit of explanation upon Cushman's hypothesis of the molecular attachment of water within and without the complex.

The author is greatly indebted to Prof. F. A. Gooch for advice and assistance throughout this work.

ART. XIV.—*The Glacial (Dwyka) Conglomerate of South Africa*; by EDWARD T. MELLOR.

[Communicated by permission of the Director of the Geological Survey of the Transvaal.]

Introductory.—Few rocks have aroused so widespread and so sustained an interest as the Glacial Conglomerate occurring at the base of the Karroo System of South Africa, generally known as the Dwyka Conglomerate. From the time when attention was first directed to it by Bain in 1856, down to the present, the Dwyka Conglomerate has continued to be a source of almost continual discussion.

In the first instance, this interest was in a great measure due to the very different views held by various geologists as to the nature of the conglomerate, and especially to the opposition offered by many to the theory of its glacial origin—a question which one may venture to regard as finally settled by the accumulation of evidence in recent years. This establishment of the glacial character of the deposits included under the term Dwyka Conglomerate, which occur over thousands of square miles in South Africa, and which correspond closely with similar formations of corresponding age in India, Australia, and South America, lends a newer and perhaps more widely spread interest to the study of this series, and of the conditions under which it was formed. To the South African geologist the rock derives additional interest from the fact that it affords the only geological horizon common to the various colonies yet established with any degree of certainty.

Nomenclature.—The term “Glacial Conglomerate” was used by E. J. Dunn on his map published in 1873* for the northern outcrops of the conglomerate, while he still retained for the more southerly occurrences an old name, “Trap Conglomerate,” used by Wyley. In the second edition of his map,† two years later, while retaining the term Glacial Conglomerate for the northern outcrops, Dunn applied the term “Dwyka Conglomerate” to those of the southern parts of Cape Colony and Natal. The term Dwyka is derived from a river of that name in Cape Colony in the neighborhood of which the conglomerate is typically developed. The name is now frequently applied to the glacial conglomerate at the base of the Karroo System generally throughout South Africa. It might perhaps be more appropriately restricted to the southern type, which, as will be pointed out, differs in some important respects from the more northerly occurrences, especially as the intermediate

* E. J. Dunn, Geological Sketch Map of Cape Colony, London, 1873.

† E. J. Dunn, Geological Sketch Map of South Africa, London, 1875.

phases have not yet been fully worked out. For the northern conglomerates the original term "Glacial Conglomerate" is as appropriate as ever, and I have preferred it in various descriptions of these conglomerates in the Transvaal.

Distribution of the Conglomerates.—The main area occupied by the Karroo System covers a large part of South Africa, including the major portions of Cape Colony and Natal, nearly the whole of the Orange River Colony and most of the south-eastern Transvaal. This area would be included roughly between lines drawn from a point on the south-east coast of Cape Colony, near to the mouth of the Gualana River, W. to near the head of the Doorn River beyond Matjesfontein, N.N.E. to the Lange Berg on the southern border of Namaqualand, NW. by Prieska and Kimberley to Middelburg and Belfast in the Transvaal, SSE. by Amsterdam to Vryheid, and SSW. to the coast of Cape Colony at the mouth of St. Johns River. This area includes most of the higher portions of South Africa, and almost the whole of it lies above a level of 3000 feet. In the Drakensberg the uppermost portions of the Karroo System attain an elevation of over 8000 feet.

The series of glacial deposits at the base of the system crop out almost continuously around the margin of the vast area occupied by it, following approximately the lines given above. Along their southern margin the Karroo rocks, particularly the Dwyka Conglomerate, have been affected by the intense folding characteristic of the southern portions of Cape Colony. There the lowest Karroo Beds are frequently highly inclined, and their outcrop is correspondingly reduced in width, but over the whole of the remainder of the area occupied by them the Karroo rocks are practically horizontal, and the outcrops of the various divisions occupy broad tracts of country. This is especially the case with the Glacial Conglomerate and lower portions of the system, which in many places form extensive outliers around the margin of the main area as above defined.

Relationships and Age.—In its southern portions in Cape Colony the Dwyka Conglomerate grades downwards into a series of greenish shales (Lower Dwyka Shales) some 700 feet in thickness, which in turn lie conformably upon the quartzites of the Witteberg Series. These, together with the Bokkeveld Beds and the Table Mountain Series, constitute the "Cape System" of Cape Colony.

Passing northwards, the Dwyka Series overlaps the lower divisions of the Cape System, which thin out in that direction, and comes to lie unconformably upon various much older systems of rocks. In all the more northerly localities where the conglomerate has been studied, it lies unconformably on the older South African rocks, the surfaces of which are fre-

quently glaciated. In Cape Colony and Natal the Dwyka Conglomerate passes upwards into the Ecce Shales, a series of shales and mudstones identical in character with the shales occurring with the Dwyka Conglomerate, and in composition corresponding with the finer portions of the matrix of that rock. The Ecce shales are succeeded by a very extensive series of sandstones and shales, attaining a maximum thickness of some thousands of feet, and including on at least two different horizons seams of coal. These, together with the Ecce Shales and Dwyka Conglomerate, constitute the Karroo System of South Africa. Intrusive sheets of diabase occur throughout the Karroo rocks, and the uppermost portion of the system consists, for the most part, of a succession of lava-flows usually amygdaloidal and of basaltic composition interbedded with sandstones containing much fragmental material of volcanic origin.

The Bokkeveld Beds of Cape Colony have yielded a numerous assemblage of fossils related to the Devonian fauna of Europe; the Witteberg beds which succeed them and underlie the Dwyka Series have so far afforded only a few imperfect specimens showing general Carboniferous affinities. With the Ecce Shales in Cape Colony and with the beds associated with the Coal Seams of the Transvaal, which sometimes, as at Vereeniging, lie immediately above the Glacial Conglomerate, a fossil flora is associated of Permo-Carboniferous age* having a number of genera in common with the lower part of the Indian Gondwana System, and the Coal Measures of New South Wales.

Compared with the southern and eastern margins of the Karroo area, the northern outcrops of the Glacial Conglomerate and associated beds show a considerable diminution in thickness, a feature shown also by the other divisions of the Karroo System. In the southern outcrops in Cape Colony the Dwyka Conglomerate has a thickness of about 1000 feet; on the north of the Colony, in the neighbourhood of Prieska, it is stated not to exceed 500 feet.† In Natal and the eastern Transvaal the thickness of the conglomerate is about 300 feet,‡ while on the northern border of the formation, in the central portions of the Transvaal, it rarely reaches 100 feet, and may be locally absent altogether. As will be seen from the descriptions given below, this difference in thickness corresponds with differences in composition, and in general characters dependent upon variations in the original conditions of deposition in the different localities.

* A. C. Seward, Notes on the Plant Remains from Vereeniging, Q. J. G. S., vol. liv, pp. 92-98. London, 1898.

† A. W. Rogers, The Geology of Cape Colony, London, 1905.

‡ G. A. F. Molengraaff, Geology of the Transvaal, Edinburgh, 1904, p. 73.

Description of the Dwyka Conglomerate in the Southern Outcrops.—The earlier studies and descriptions of the Dwyka conglomerate were confined to its occurrence in the southern portions of Cape Colony and in Natal. In the southern examples especially the conglomerate has certain characteristics which led to much controversy as to its origin. Its appearance in the Dwyka locality was thus described by Mr. E. J. Dunn: * "The conglomerate consists of a bluish grey base so fine that its constituents are not resolvable, except under high magnifying power, and then no crystals are disclosed; it appears to be a very fine indurated mud; in this base are enclosed boulders, pebbles, angular fragments, and grains of a great variety of rocks, such as granite, granulite, gneiss, mica, and other schists, quartz rock, hard sandstone, jasper, hornfels, quartz, small pieces of felspar, etc."

The included fragments, which range in size from mere grains to boulders several feet in diameter, are distributed in the matrix without definite arrangement. The rock as a whole is very hard and fractures pass indifferently through matrix and boulders alike. By weathering it frequently produces a yellowish clay, through which the hard rock fragments and boulders of the original conglomerate are scattered. Besides the conglomerate beds, other shaly beds occur devoid of included fragments. Individual beds persist over long distances, maintaining at the same time their distinctive lithological characters. The conglomerate beds vary from a few inches to hundreds of feet in thickness. In the southern parts of Cape Colony the conglomerate often shows a schistose structure resulting from the earth movements which have affected that area—to the effects of which is probably also due in part the extreme hardness of the southern rock as compared with its northern representative.

Various theories concerning the Origin of the Dwyka Conglomerate.—The dark green color of the conglomerate, its richness in minerals not usually abundant in rocks of sedimentary origin, including much chloritic material, its extreme hardness, its crystalline appearance and the frequent absence of bedding through great thicknesses of rock, disposed almost every observer, including many geologists of wide experience, to attribute to the conglomerate an igneous origin. Expressive of these views are the following names applied to the rock at various times by different workers: "Claystone-porphry," "Trap-conglomerate," "Melaphyre-breccia," "Volcanic-breccia," "Trap-breccia." Many and various were the theories advanced at different times and by different observers to

* E. J. Dunn, Report on the Camdeboo and Nieuwveldt Coal, p. 7, Cape Town, 1879.

account for the peculiar characters of the conglomerate. A. G. Bain, "The Father of South African Geology," who first described the Dwyka Conglomerate in 1856, suggested that it represented a flow from an immense volcano. Prof. A. H. Green thought it to be a "coarse shingle formed along a receding coast-line," while from Green's specimens Sir A. Geikie and Dr. F. H. Hatch considered it had the aspect of a volcanic breccia. The majority of South African geologists favored the igneous theory, accounting for its peculiar characters and occasional stratification by referring its origin to submarine volcanoes.

A glacial origin was first attributed to the conglomerate in 1868 in a paper on the Geology of Natal by Dr. P. C. Sutherland,* who had previously regarded the rock as a lava-flow. Sutherland, who was familiar with the conglomerate in Natal, where the rock has more the features of a terrestrial glacial deposit, and rests in places upon striated rock surfaces, clearly stated the real character of the rock. The glacial view received early support from Stow,† who, however, referred the glaciation to a much later period, and subsequently from Schenck,‡ Dunn, who did so much to work out the main features of the distribution of the Glacial Conglomerate as shown in the various editions of his "Geological Sketch Map of South Africa," regarded the rock as largely due to the action of floating ice, an agent which no doubt had much to do with the southern deposits.

It is only quite recently, however, that owing to the accumulation of evidences§ from various localities in South Africa the glacial origin of the Dwyka Conglomerate has received anything approaching general acceptance.

Recent Studies of the Glacial Conglomerate.—In 1898 Dr. Molengraaff|| published a description of the Dwyka Conglomerate, and overlying Ecce beds, as developed in the Vryheid district of the Transvaal, to the north of the Natal border (now included in the latter colony). In the Vryheid district the Dwyka Conglomerate averages about 300 feet in thickness, and lies unconformably upon an old land surface composed mainly of the hard quartzites and shales of the Barberton formation—the surfaces of which are frequently polished and striated. Both the conglomerate and succeeding Ecce Shales offer good

* P. C. Sutherland, On the Geology of Natal, Pietermaritzburg, 1868.

† G. W. Stow, On some Points in S. A. Geology, Q. J. G. S., vol. xxvii, pp. 497-548. London, 1871.

‡ A. Schenck, Die Geologische Entwicklung Südafrikas, Pet. Mitt., Band xxxiv. Gotha, 1888.

§ See recent reports of the Geological Surveys of Cape Colony, Natal and the Transvaal.

|| G. A. F. Molengraaff, The Glacial Origin of the Dwyka Conglomerate, Trans. Geol. Soc. S. A., vol. iv, 1898.

opportunities for study in the many sections exposed in the deeply cut valleys of the eastern rivers. In this district the Dwyka Conglomerate includes both unstratified and stratified portions, in each of which faceted and striated bowlders are abundant, together with many angular and sub-angular rock fragments. The stratified beds are sometimes almost devoid of bowlders and pebbles, and include mudstone and shales, the latter indistinguishable from the overlying Ecca Shales into which the Dwyka Conglomerate gradually passes.

In 1899 Messrs. Rogers and Schwartz* studied the Glacial Conglomerate in the Prieska district in the north of Cape Colony. They found the Conglomerate here to present all the features of a true ground moraine, with abundance of faceted and striated bowlders; and lying unconformably upon all the older rocks of the district, fragments of which occur in the conglomerate and which afford fine examples of "roches mon-tonnées" and striated surfaces. The direction of the striæ and distribution of the bowlders point to a movement from the north southwards.

In his report for the same year Dr. Corstorphine† summed up the results obtained in the north and south of Cape Colony and elsewhere, and compared the features of the northern and southern deposits, contrasting the northern Glacial Conglomerates, possessing the characters of a ground moraine, with the southern Dwyka, which is to be looked upon as "a sediment formed under a probably inland water, into which there floated the icebergs calved from the front of the glacier or glaciers on the northern shore."

The identity in character of the Glacial Conglomerate with a true ground moraine, seen in the northern parts of Cape Colony, comes out with even greater clearness along the northern edge of the main area occupied by the Karroo System in the Transvaal.

The Glacial Conglomerate in the Transvaal.—In the central portions of the Transvaal, and particularly in a district lying along the eastern railway line from Pretoria to Middelburg, I have recently mapped many outliers of Karroo rocks isolated by the progress of denudation from the main body, which covers extensive areas to the south and south-east. These outliers sometimes include portions of the sandstones, grits, and shales associated with coal-seams which form the upper portion of the Karroo System as developed in this part

* Rogers and Schwartz, Ann. Rep. of the Geol. Commission, 1899. Cape Town, 1900. On the Orange River Ground Moraine. Trans. Phil. Soc. S. A., vol. xi, part 2, 1900.

† G. S. Corstorphine, Ann. Rep. of the Geol. Commission, 1899. Cape Town, 1900. (Full references to the previous literature will be found in this paper.)

of the Transvaal. They are, however, frequently reduced to patches consisting almost entirely of the Glacial Conglomerate and associated beds. The copious sandy drift shed by these outliers frequently renders their examination difficult, but in some cases they offer more than usually good opportunities for the study of the Glacial Conglomerate and its relationships to the underlying rocks. In the district here more especially referred to, the glacial deposits consist for the most part of a conglomerate showing all the characters to be expected in one formed beneath an extensive ice-sheet. This conglomerate is

1



very irregular in distribution, and varies greatly in thickness within short distances, partly in consequence of its original deposition on an irregular land surface, and partly as a result of subsequent denudation. Its average thickness is about fifty feet. In depth the rock is sometimes greenish in color, but at the surface it is usually light yellow, and crops out in characteristic humpy masses (see fig. 1). The matrix is a sandy-looking material consisting of sharply angular fragments of quartz and of various rocks—quartzites, hard shales, felsites, granophyres—common in the district. These angular fragments vary in size from the smallest particles to pieces several inches in diameter. Irregularly distributed through the matrix, and with a conspicuous absence of any sort of arrangement as to size or orientation, occur abundant pebbles and

bowlders of very miscellaneous composition, and ranging in size up to a diameter of eight or ten feet. These pebbles and bowlders are frequently faceted, and those of very hard materials are always highly polished, while bowlders of somewhat softer nature, especially if fine in grain, such as hard shales and weathered felsitic rocks, frequently show striations. A network of cracks in some cases divides the pebbles into a number of fragments which have been again cemented into a whole. In any particular locality there is always a preponderance of bowlders derived from rocks which locally underlie the Glacial Conglomerate, associated with others easily recognizable as derived from more distant sources, which are always to the north of the present position of the bowlders. Thus along the eastern railway line, to the south of an area mainly occupied by the Waterberg Formation and the Red Granite, the Glacial Conglomerate contains an abundance of bowlders derived from these rocks. South of the outcrop of the hard white Magaliesberg quartzites, fragments of the white quartzites are very abundant. Those lying nearest to the ridge from which they were derived are angular and frequently of huge dimensions, so that when weathered out and lying on the surface they are conspicuous objects at a distance of two or three miles. On the eastern Witwatersrand the conglomerate contains many bowlders derived from the Rand Series together with others formed of the hard cherts of the Dolomite to the north. Except quite locally, the lower and more massive portions of the conglomerate rarely show any traces of bedding, but are occasionally traversed by irregular partings dividing the rock into rude sheets with undulating billowy surfaces. Towards the upper portions of the conglomerate, lenticular beds of fine-grained massive sandstone frequently occur, together with patches of white and cream-colored shales and mudstones. The shales appear to have been formed in local pockets below the ice. They consist of the finest glacial mud. The examination of a district of some hundreds of square miles in extent leads to the conclusion that at the termination of the period during which glacial conditions obtained, the country was left covered with an almost complete mantle of glacial deposits, quite similar in character and distribution to those remaining in other parts of the world from extensive glaciation of more recent date. After the cessation of glacial conditions the conglomerates and associated deposits appear to have suffered a certain amount of sub-aërial erosion and denudation, during which materials derived from the glacial deposits underwent re-arrangement and re-deposition, giving rise in some cases to beds of conglomerate very similar in composition and general appearance to those of glacial origin, with

which they are liable to be confused, but differing in the more orderly arrangement of their materials, including a definite orientation of the pebbles and bowlders. These secondary conglomerates occasionally occur at the base of the purely sedimentary series which succeed the true glacial deposits, and by which as a result of a period of long continued subsidence the latter were ultimately entirely covered. This sedimentary series included the succession of beds constituting in the Transvaal area the upper portion of the Karroo System. Later formations were also possibly represented but of these no ves-

2



tige has hitherto been discovered in the Transvaal. Raised subsequently to an average elevation of 5000 feet above the sea, the Karroo System has been again subjected to denuding forces and the removal of the overlying sandstones, shales, and grits of the Coal Measures has laid bare extensive areas of the underlying Glacial Conglomerate.

Although modified by the double process of denudation to which it has been subjected, it still presents in its distribution a striking similarity to that of more recently formed glacial deposits. Following the contours of the land surfaces upon which it was originally laid down, it ranges within distances of a few miles through variations in elevation of three to five hundred feet. It is frequently well developed on one slope of a hill and entirely absent from the other. When protected

from erosion it fills preëxisting valleys, and is usually especially abundant below ancient escarpments of the older rocks, and in such places boulders often of very large size, attaining in some cases eight or ten feet in diameter, are exceptionally numerous. After the complete weathering away of the matrix the boulders remain abundantly scattered over areas previously occupied by the conglomerate. (See fig. 2.)

Glaciated Surfaces below the Conglomerate—Direction of Ice-Movement.—The progressive removal by denudation of the Glacial Conglomerate around the margins of the areas now occupied by the Karroo System and its outliers continually lays bare fresh portions of the underlying old land surface. Where these include outcrops of hard and moderately fine-grained rocks, the latter frequently present excellent examples of glacially striated surfaces,* some of which are represented in the photographs reproduced in figures 3, 4, 5. Striated surfaces of this kind were long ago described by Sutherland in Natal, by Griesbach in the same colony, by Dunn and Schenck in the neighbourhood of the Vaal River, and more recently by Molen-graaff in the South-Eastern Transvaal, and by Rogers and Schwartz in the Prieska district in the north of Cape Colony. While working on an area lying about 25 miles east of Pretoria in 1903, I found the surface shown in figure 3; and later those in figures 4 and 5. These latter occur on the edge of an outlier of Karroo rocks some 25 miles further east, which includes the coal seam worked at the Douglas colliery. I have since met with many similar surfaces distributed over an area of some 300 square miles. The striation in most cases is exceedingly clear, and the direction of ice-movement easily determined and remarkably consistent. In all the examples found it only varies within a few degrees from magnetic north and south, the direction of movement being in a southerly direction, which is also true in general for the other districts in South Africa where striated surfaces have been found. This consistency of direction over so considerable an area and in the case of surfaces lying 25 miles apart, points to the existence of an ice-sheet of considerable magnitude, rather than to that of a number of more or less isolated glaciers, a conclusion which is supported by the nature of the land surface laid bare by the disappearance of the Karroo deposits.

Where the Waterberg Sandstone Formation, which occupies much of the district here referred to, has been long exposed to ordinary denudation, the rivers cut deep valleys and gorges in the sandstone, giving rise to very varied and occasionally rug-

* E. T. Mellor, On Some Glaciated Land Surfaces occurring in the District between Pretoria and Balmoral. Trans. Geol. Soc. S. A., vol. vii, part 1, 1904.

8



4



ged scenery. Where, however, the overlying Glacial Conglomerate is only now in process of removal, the country retains the rounded outlines characteristic of a glaciated landscape.

Northern extension of the Glacial Conglomerate.

I have recently met with good examples of the Glacial Conglomerate much further to the north than any hitherto described.* (Figures 1 and 2.) These are situated near the junc-

5



tion of the Elands and Olifants Rivers, about 90 miles north of the latitude of Johannesburg, and are interesting for the additional light they throw upon the northward extent of the country subjected to glacial action in early Karroo times.

EXPLANATION OF FIGURES.

FIGURE 1.—Glacial conglomerate near the junction of the Elands and Olifants Rivers, Transvaal (75 miles NE. of Pretoria).

FIGURE 2.—Weathered-out Glacial conglomerate, same locality. The figure stands upon grits of the upper Karroo formation.

FIGURE 3.—Glaciated surface. Elands River Valley (25 miles E. of Pretoria).

FIGURES 4 and 5.—Glaciated surfaces north of Balmoral (50 miles E. of Pretoria).

The striated rocks are red quartzitic sandstones of the Waterberg Series.

Geological Survey, Pretoria, Transvaal.

* E. T. Mellor, *Outliers of the Karroo System near the Junction of the Elands and Olifants Rivers in the Transvaal*, Trans. Geol. Soc. S. A., vol. vii, part 3, 1904.

ART. XV.—*The Formation of Natural Bridges*; by
HERDMAN F. CLELAND.

UNTIL recently the text-books of Geology and Physical Geography have given the idea, whether intentionally or not, that natural bridges are universally formed by the partial caving in of a long cavern, the bridge being that portion of the roof strong enough to span the cavity.* The belief seems to be prevalent that these cavities extended for long distances, a condition comparable to that which would exist if the greater part of the roof of Mammoth Cave should fall in, leaving a small portion as a bridge. This theory is simple and logical and is one which immediately appeals to the reader, but, as will be seen from the examples cited in this paper, not only is it not of universal application but it must be exceptional rather than otherwise. The writer was led to this study by an examination of the natural bridge near North Adams, Mass. which has long been considered to be a typical example and proof of the formation from caverns.

The North Adams Natural Bridge spans Hudson Brook and has been an object of more than local interest for many years both because of its natural beauty and because of the rarity of these objects. Hudson Brook is a small stream emptying into Beaver Creek, a tributary of the Hoosick River. From the dam (shown in the sketch fig. 1) to the pre-glacial valley the brook flows through a gorge 30 to 60 feet deep and from 5 to 40 feet wide, the average width above the bridge being from 1 to 10 feet and below from 10 to 30 feet. This gorge is cut in a coarsely crystalline marble which, because of its color and texture, presents a striking appearance. The rock is Cambro-Silurian and belongs to the Stockbridge formation.

The top of the natural bridge is 44 feet above the water of the stream and the bridge itself is about 8 feet thick. The span of the bridge is less than 10 feet long and the width at present 25 feet, but at one time it probably extended a short distance farther south where it is now fallen in. It is extremely difficult to take a good photograph of the bridge because, as will be seen from the sketch, the stream turns sharply both above and below. Because of this condition it was found necessary to make a drawing, in order to give a correct idea of its appearance.

Prof. E. Hitchcock described the North Adams Natural Bridge and published a rough drawing of it in 1841.† Concerning this drawing he says, "I thought it better that a sketch

* Chamberlain and Salisbury, *Geol.*, vol. i, pp. 145-147.

† *Geology of Mass.*, by Edward Hitchcock, vol. i, 1841, pp. 287-288.

should be taken by one not at all accustomed to drawing, than that no memento be left of this interesting place," (there was danger at that time that the bridge might be destroyed by the quarry-men.) Hovey* in his "Celebrated American Caverns" describes this bridge but gives the locality as Adams, Mass.

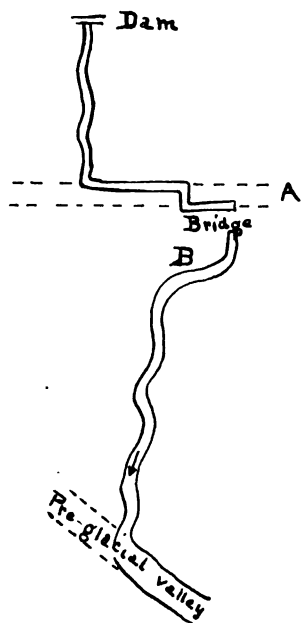


FIG. 1.—Sketch map of Hudson Brook, Mass., showing the position of the natural bridge, the joint planes A-A, and the pre-glacial valley.

The explanation of the formation of the North Adams Natural Bridge, as given by Hitchcock and accepted by Hovey, is that it is the section of the roof of a cavern, the ends of which have fallen in. In illustration of this point, Hovey states that, "the combination of cave, chasm and natural bridge, on Hudson Brook, Mass. is even a better example (than that of the Natural Bridge in Virginia) of the same thing," i. e., "that what are now open canons were once caves, the arch being merely a remnant of an ancient cave roof."

On examining the course of the stream and the rock in the vicinity of the North Adams Natural Bridge one is struck with the width of the joints, and the fact that the stream has, for a portion of its course, followed the joint planes. In the upper part of the accompanying sketch (fig. 1) the relation of the stream to the joint planes is indicated by the dotted lines A-A. The channel through which the stream flowed previous to the formation of the bridge is also well marked a few feet to the west at B. A pot-hole situated near the edge of the gorge at B is further evidence of the former position of the brook.

The bridge was probably formed as follows: When the stream flowed into the gorge through the ancient channel, it plunged over a fall into the pre-glacial valley. Some of the water in the joint plane nearest the present bridge seeped through an approximately horizontal crack a short distance under the present arch of the bridge. The solvent power of

* "Celebrated American Caverns," H. C. Hovey, pp. 14 and 206.

the water containing carbon dioxide (CO_2) gradually increased the size of the crack until it was still further enlarged by the erosion of the stream. The stream was finally entirely diverted from its former channel at B to its present course. The gorge from the dam to the pre-glacial valley is a succession of broken pot-holes varying in size up to 6 or 8 feet in diameter, showing

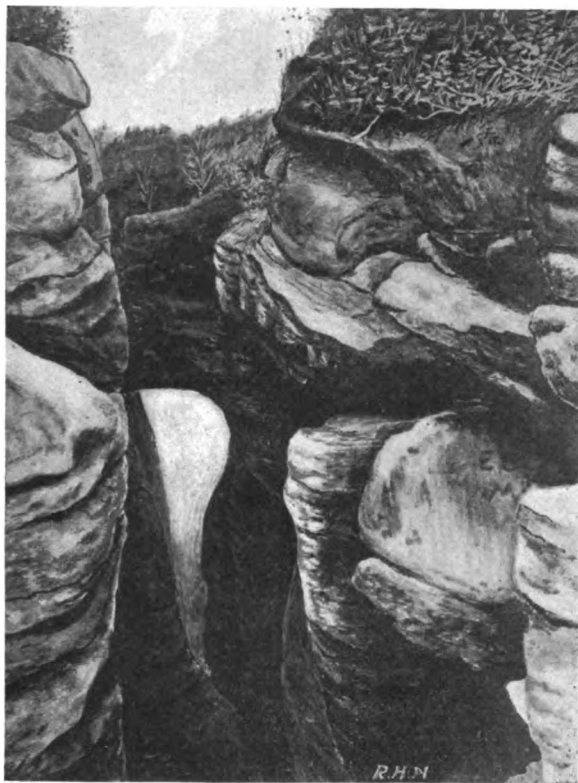


FIG. 2.—The North Adams Natural Bridge as seen from the south.™ Formerly the bridge probably extended nearly to the foreground of the picture.

that after the tunnel was made the gorge was largely excavated in this way. The pre-glacial valley in which the Hudson Brook flows below the gorge is broad but to some extent choked with glacial drift.

The origin of the famous Natural Bridge of Lexington, Va.,* as explained by Walcott, was similar to that of the Natural Bridge of North Adams, Mass., but is on a larger scale. Before

* National Geographic Magazine 1898, vol. v, p. 59.

the formation of the bridge the stream, which now flows under, then flowed upon the surface of what is now the arch and probably plunged over a fall a short distance below the present site of the bridge. While the stream was flowing over this fall a portion of the water was percolating through a joint plane or other crack up stream and discharging into the stream under the fall, enlarging its passage by its solvent power. In the course of time this passage became sufficiently large to contain all of the water of the stream, and the bridge resulted. It is not possible to say what the length of this underground passage was. It must have been somewhat longer than at present, but "whether one hundred feet or several hundred feet" it is not possible to determine.

The description of some wonderful natural bridges in Utah,* in a recent paper, suggests an explanation similar to that given above, except that, in the case of these bridges, the rock is said to be a sandstone (pink or gray) instead of a limestone. The most probable explanation is that, at one time, the river flowed over a fall a short distance below the lowest bridge and that, as the stream was cutting back, a portion of the water was pouring through a fissure up the stream and reappearing at the brink of the fall, dissolving out the cement of the sandstone along its course. This underground passage was gradually enlarged by the washing out of the unconsolidated sand, resulting in a tunnel of sufficient size to hold the entire volume of the stream. After this event the valley was eroded to nearly its level. This process was repeated three times with the formation of three bridges. When it is remembered that one of these bridges spans a canyon 335' wide, that the lower side of the arch is 357' above the stream and that the material of which they are constructed is sandstone, it will be seen that any explanation requiring a tunnel of great size extending for a long distance is untenable. It is, however, unsafe to do more than speculate upon the formation of these bridges, since so little is known of the rock of which they are composed.

In the Yellowstone National Park occurs a small natural bridge of rhyolite. The bridge consists of two vertical slabs of lithoidal rhyolite, parts of the contorted layers of lava flow, which stand nearly vertical in this place.† They are slightly curved and are separated by open crevices with roughened scoriaceous walls. Of the two slabs forming the ledge the eastern is two feet thick at its ends and thinner in the middle. There is a space of two feet between it and the western slab, which is four feet thick. "The span of the arch is about 30 feet and it rises about 10 feet, the top of the bridge being some

* W. W. Dyar, *Cent. Mag.*, vol. lxviii, 1904, pp. 505-511.

† *Geol. of Yellowstone Nat. Park*, U. S. G. S. Mon., vol. 82, pt. II, pp. 386-7.

40 feet above the stream.” The explanation of the formation of the bridge is as follows: The stream which flows underneath



FIG. 3.—Vertical plates of rhyolite. Yellowstone Natural Bridge. (Mon. U. S. G. S. 82, pt. II, plate 49.)

the bridge has been able to excavate, owing to a former waterfall and the peculiar platy structure of the rhyolite, in which curved layers of extremely different physical texture and friability offered a favorable site for attack by frost and water.

The formation of lava bridges is usually explained as follows: The surface of a lava flow cools and hardens while the interior is still in a molten condition. As a result of this condition, if the molten rock beneath continues to flow, a tunnel will result. Such tunnels are of common occurrence on Mt. Vesuvius, the volcanoes of the western states and in other volcanic regions. From such a tunnel a bridge might be formed by the caving in of the greater part of the roof. A study of the photograph (fig. 3) showing the structure of the lava of which the Yellowstone Natural Bridge is formed shows that such an explanation is untenable in this case at least, the rock being composed of approximately vertical plates of lava of different degrees of compactness. The writer has not made a study of other lava bridges, but it seems probable that the mode of formation of the Yellowstone bridge may be exceptional for bridges of this character.

In each of the cases cited the top of the bridge was formerly a portion of the bed of the stream. If natural bridges were formed as commonly supposed, it would be unusual to find that a surface stream had once been superimposed upon the cavern for its entire length. There is, for example, seldom any relation between the surface topography of a country and the underground passages of extensive caves.

Occasionally a small natural bridge occurs near the opening of a cavern or where a spring flows from beneath a cliff. Such a bridge is the sandstone arch spanning a spring which emerges from beneath the sandstone capping of Lookout Mountain near Chattanooga, Tenn. The bridge is formed by the widening of a transverse joint, first by weathering alone and later by the combined action of weathering and erosion, thus separating the bridge from the cliff. The breadth of the span was increased largely by weathering.

The conclusion to which one is led by this study of natural bridges from different parts of the United States and composed of various kinds of rocks—marble, limestone, sandstone, and lava—is that, although bridges may be formed, and undoubtedly have occasionally been formed, by the partial falling in of the roof of a long underground tunnel, the usual mode of formation is that described above. It should, however, be said that examples exist concerning which it is difficult to say which mode of formation was the more prominent.

Williams College.

ART. XVI.—*Quartz from San Diego County, California*;*
by G. A. WARING, Stanford University, California.

IN quartz crystals occurring in the pockets of the gem-bearing pegmatite veins of the Pala and Rincón districts, San Diego County, California, several peculiarities of crystallization have been observed, which it is believed have not before been described. These crystals occur attached to the sides of the cavities, associated usually with albite and orthoclase. The most remarkable feature about them is the common development of tetartohedral faces.

On two crystals, figs. 3 and 7, the facial angles were measured by means of a Fuess reflecting goniometer, and the following rare faces determined, according to Bravais-Miller system of notation.

On the small crystal, fig. 7:—

	Measured.	Given by Dana.
$m \wedge \Gamma$ (40 $\bar{4}$ 1)	11° 12'	11° 8'
$m \wedge x$ (51 $\bar{6}$ 1)	11° 50'	12° 1'

On the crystal, fig. 3:—

	Measured.	Given by Dana.
$m \wedge x$ (51 $\bar{6}$ 1)	11° 27'	12° 1'
$m \wedge y$ (41 $\bar{5}$ 1)	$\left\{ \begin{array}{l} 14^\circ 8' \\ 14^\circ 54' \\ 14^\circ 10' \end{array} \right.$	14° 35'
$m \wedge s$ (11 $\bar{2}$ 1)	37° 39'	37° 58'

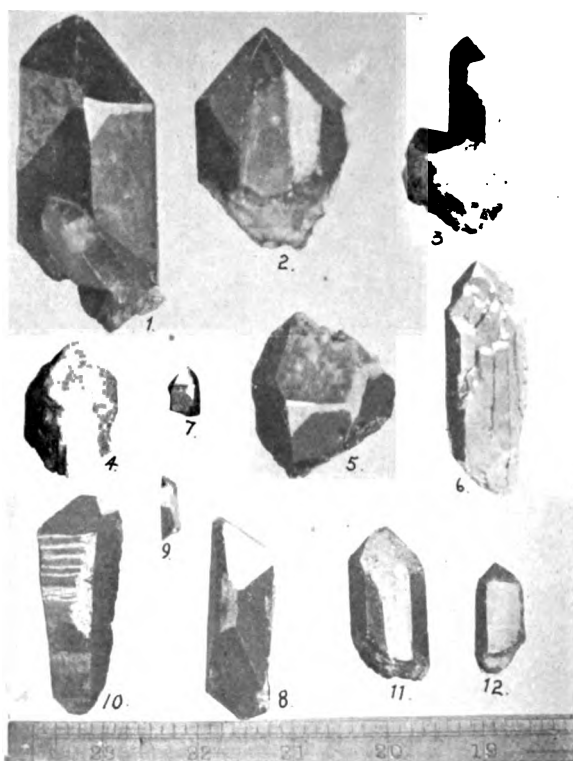
The Γ (40 $\bar{4}$ 1) and M (30 $\bar{3}$ 1) faces also are present on this crystal, determined by measurement with the contact goniometer, and the u -face (31 $\bar{4}$ 1) is also developed; it is distinctly visible with the pocket-lens, but too small to be measured with certainty. It has the terminal pyramids partly developed at the other end also, and imperfectly showing the rare faces. It is intergrown with a left-handed crystal which on the face preserved exhibits the faces s (21 $\bar{1}$ 1), x (61 $\bar{5}$ 1) and Γ (40 $\bar{4}$ 1).

Twinning is common and, so far as observed, is always according to the Dauphiné law. The upper part of the crystal shown in fig. 3 is such a twin, of two right-handed individuals very perfectly joined, the twinning plane but faintly shown by cloudy patches within the crystal.

Fig. 1 is a twin of two left-handed individuals, the plane of twinning being well marked on the surface by a discontinuity in the prismatic striations, and by a plane of dark patches

* Sincere appreciation is expressed to Dr. M. Murgoci of Vienna for assistance in the measurement of the inter-facial angles, and to Dr. J. P. Smith of Stanford University for advice and aid in the preparation of this article.

within. This twinning is also markedly shown at the junction of the prism and pyramid faces, by the development on one individual of the e ($50\bar{5}1$) face and on the other of the Γ ($40\bar{1}1$) face. This twin has developed on one member between the m and z faces the x ($6\bar{1}51$), Γ ($40\bar{1}1$) and e ($50\bar{5}1$) faces, and between m and r on the adjacent edge to the right, the x ($6\bar{1}51$)



Group of quartz crystals from Pala and Rincon,
San Diego County, California.

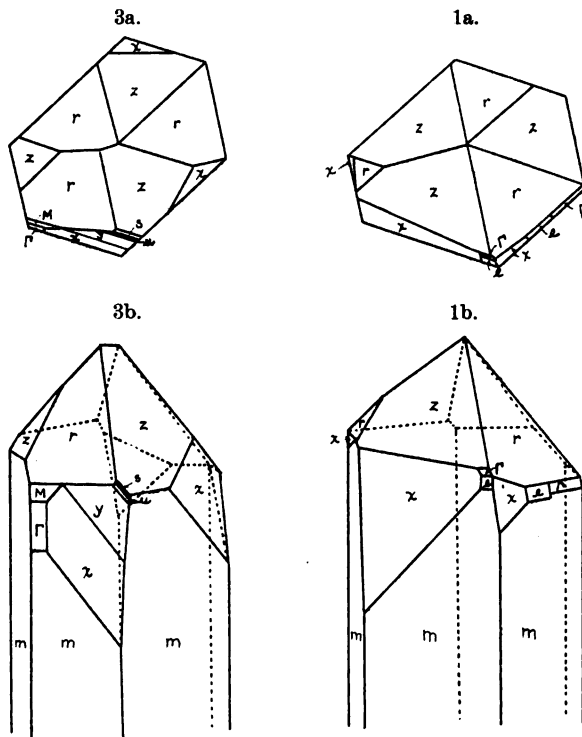
and e ($50\bar{5}1$) faces; while the other member has developed only the Γ ($40\bar{1}1$) face.

In figs. 3a, 3b and 1a, 1b are given orthographic and clinographic projections of the two crystals numbered 3 and 1 respectively in the group of crystals above, showing the relative size and positions of the rare faces.

Figs. 2 and 4 also are distinctly marked twins; the one shown by a joint or break along the prism face, the other by a distinct difference in opacity of the two members.

Deformation, or abnormal growth, is also met with. Fig. 6 is an example of parallel growth, while figs. 8, 9 and 10 are distorted forms. In fig. 10 the crystal is placed with its major axis perpendicular to the paper, so that one is looking down on the apex of the pyramid.

Corrosion or etching of the pyramidal faces, while those of the prism are unaffected, is illustrated in figs. 11 and 12.



Orthographic and clinographic projections of quartz crystals from Rincon, California, from figs. 8 and 1, p. 126.

One other extremely interesting point is that of the evidence of secondary crystallization, as shown by the filling up of the x , y , and $e-M$ faces to a level, or nearly so, with the prism face. This is well exhibited in figs. 5 and 10.

While the s face occurs rather commonly elsewhere, the x and y faces are of much rarer occurrence. It is therefore worthy of note that upon the crystals of this region it is the trapezohedral faces that develop most frequently, while the s face, the trigonal pyramid, is seldom found.

Stanford University, California.

ART. XVII.—*On the Radio-active Properties of the Waters of the Springs on the Hot Springs Reservation, Hot Springs, Ark.*; by BERTRAM B. BOLTWOOD.*

THE Hot Springs Reservation is situated in Garland County, Ark., on the western slope of the Hot Springs Mountain, a spur of the Ozark Range. On the grounds of the Reservation the thermal waters rise through over fifty separate sources, and the total flow is estimated to be over 800,000 gallons in twenty-four hours.

During the summer of 1904, at the direction of the Secretary of the Interior, a thorough examination of the waters of these springs for radio-active properties was carried out by the writer. Samples of the waters were collected at the springs, some in July by Dr. Joseph H. Pratt, and the remainder in August by Mr. Martin A. Eisele, Superintendent of the Reservation. The samples were taken directly from the springs and were immediately introduced into large, glass receptacles. These receptacles were tightly corked and the corks were covered with a heavy coating of hot sealing-wax, thus hermetically sealing up the sample contained within them. The samples were shipped by express to New Haven, Conn., where the tests described in this paper were conducted. The samples were collected and shipped in separate lots of six each, and the tests were carried out as soon after the receipt of the samples as possible. The average time required for the transportation of the samples by the express companies was about seven days.

The constituents tested for were radio-active gas (emanation) and radio-active solids. An examination was also made of the tufa deposited by certain of the springs in order to determine whether this contained any radio-active substances.

The methods employed in the determination of the radio-active gas contained in the water, and in the determination of the presence of radium salts in solution, have already been described† in an earlier paper. The plan there followed of expressing the activity of the dissolved radium emanation in terms of the uranium equivalent has been modified to the extent of introducing a correction for the proportion of radium emanation lost by the pulverized sample of uranium mineral used for determining the standard.‡ Since the quantity of

* Published with the permission of the Secretary of the Interior.

† This Journal, xviii, 378, 1904.

‡ A method for determining the proportion of emanation which spontaneously escapes from the cold, finely-ground mineral has been described in the Phil. Mag. (6), ix, 599.

radium associated with a definite weight of uranium in a radio-active mineral has been shown* to be a perfectly definite and unvarying quantity, this method of expressing the activity of a given quantity of emanation affords a convenient and accurate standard for the comparison of samples of water from different sources.

Samples of water from forty-four of the different hot springs were examined. The properties of the gaseous, radio-active constituent were found to be identical with those of the radium emanation. The activity of the gas fell to one-half value in about 3.9 days and the active deposit, after two hours from the start, had a half-value period of twenty-eight minutes.

In the following table are given the quantitative results of the examination of the waters. The first column gives the laboratory number of the sample, the second column contains the number representing the activity of the gas actually obtained from one liter of water expressed in terms of the uranium standard,† the third column gives the number of days which transpired from the time of collecting the sample to the time of testing the water, and the fourth column gives the initial activity of the water (per liter) as calculated from the equation: $I_0 = I_e^{-\lambda t}$.

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
22A	0.9	8	3.7
23A	3.8	7	14.4
24A	1.8	7	6.8
25A	3.9	7	15.1
26A	8.4	7	31.9
27A	0.4	8	1.6
29A	6.3	7	23.9
30A	12.5	7	49.0
32A	7.6	7	28.9
33A	3.1	7	11.8
34A	7.7	7	29.3
35A	17.2	7	65.4
36A	14.4	7	54.7
37A	2.1	9	10.3
38A	0.9	7	3.4
39A	8.5	9	41.6
40A	2.6	10	15.3
41A	1.3	10	7.7
43A	1.3	7	4.9

* Boltwood, this Journal, xviii, 97; Phil. Mag. (6), ix, 599.

† The number denotes the weight in grams of the quantity of uranium in a radio-active mineral which is associated with a quantity of radium, the total emanation from which would be equivalent to the emanation obtained from one liter of the water.

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
44A	5.8	7	22.0
45A	0.9	9	4.4
46A	1.8	9	8.8
47A	8.1	6	23.5
48A	1.3	7	4.9
50B	1.7	9	8.3
51B	1.3	8	5.3
52B	0.17	6	0.5
54B	0.4	7	1.5
55B	2.1	7	8.0
56B	0.2	8	0.8
59B	3.4	7	12.9
60B	1.8	7	6.8
61B	4.9	6	14.2
62B	3.9	7	14.8
63B	25.6	7	97.3
64C	9.0	6	26.1
65C	5.0	6	14.5
66C	10.5	6	30.5
67C	2.5	8	10.2
68C	9.0	6	26.1
69C	13.8	6	40.0
70C	91.6	6	265.6
71C	3.6	7	13.7
72C	3.9	7	14.8

Radio-activity of Water on Standing.

A sample of water No. 39A was sealed up in a large receptacle holding about twelve liters and allowed to stand undisturbed for thirty-two days. At the end of this period the activity of the gases contained in the water was tested. The activity was very low and was not greater than the natural residuum which would remain from the emanation originally present. This indicated that the water contained no radium salts in solution.

A quantity of water No. 70C, from which the gas had been removed by boiling after acidifying with acetic acid, was allowed to stand in an open vessel for two days, and was then sealed up for twelve days longer. At the end of this time it was tested for radio-active gases, but no radio-activity could be detected in the gas which was obtained during the second boiling operation. This also indicated the absence of radium salts in solution.

Residues from Water.

About twenty liters of water from sources No. 39A and 67C were evaporated to dryness and the residue tested in the elec-

troscope. No indication of any activity in the solid substance could be obtained. The mineral salts in the residue were converted into chlorides, dissolved in water, and the resulting solution was sealed up for thirty days. The accumulated gases were boiled off and tested. The observed radio-activity was too slight to measure with any accuracy, and corresponded at most to the smallest detectable trace of radium salts in the waters.

Tufa from Springs.

On issuing from the ground a number of the springs form a deposit of "tufa," consisting chiefly of carbonate of calcium. A sample of this material weighing 100 grams was dissolved in dilute hydrochloric acid and the gas evolved was conducted into a strong solution of sodium hydroxide. A small residue of gases not absorbed by the sodium hydroxide solution was examined in the electroscope. The radio-activity of these gases indicated that the quantity of radium present in the tufa was less than one-millionth of the quantity of radium associated with an equal weight (100 grams) of uranium in pitchblende.

Gas from Springs.

Samples of the gases which rise with two of the springs were tested under conditions identical with those under which the gas obtained on boiling the water was tested. The measurements were carried out eight days after the gases had been collected at the springs, and the activity of the gases was found to be less than that of equal volumes of gases obtained by boiling the waters from the same springs.

Water from Cold Springs.

In addition to the hot springs, there are on the grounds of the Reservation two cold springs, situated on the northern slope of Hot Springs Mountain, and issuing from the earth about 800 feet from the nearest hot spring. An examination of the waters of these springs gave the following results:

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
73D	6.0	6	17.4
74D	18.1	10	106.8

Discussion of Results.

One of the most interesting results of the present investigation is the demonstration of such marked variations in the activity of the water from such a closely related series of springs. The temperature of the different springs varies from

35° C. to 64° C. and the total solids in the waters vary from 170 to 310 parts per million,* while the average amount of solids in all the springs is between 275 parts and 280 parts. In only a few of the springs do the solids fall below 270 parts or rise above 290 parts per million.

In their general chemical characteristic the waters from the different springs show a marked resemblance to one another, and such a great variation in the activity of the different waters was entirely unexpected. It will be noticed that the most active spring water (No. 70C) is over 500 times more active than the least active (No. 52B).

That these variations were in no way due to the conditions under which the particular samples were collected and tested was shown by the fact that duplicate samples collected at different times and by different persons gave closely agreeing results.

All of the hot springs are situated on a narrow strip of land about 500 yards in length. No connection can be discovered between the location of the springs and their radio-active properties. The more active springs are widely scattered and adjacent springs usually show great differences in the radio-active properties of their waters. As a general summary it can be stated that it has been found impossible to establish any connection between the temperature, flow, location or chemical composition of the waters of the springs and the observed differences in the radio-active properties.

Another interesting point is brought out by the relatively high activity of the two cold springs as compared with the least active hot springs. It will be noted that the second most radio-active water was that from the cold spring No. 74D. This would seem to indicate that the thermal qualities of the waters and their radio-active properties are due to quite independent causes.

The results of this investigation demonstrate the necessity of the quantitative examination of the water from each separate spring in order to obtain a definite knowledge of the radio-active properties of the waters derived from a number of adjacent, individual sources.

139 Orange St., New Haven, Conn., June, 1905.

* A very complete chemical examination of the waters of these springs has been made by Mr. J. K. Haywood of the U. S. Department of Agriculture. The results have been published under the title of "The Hot Springs of Arkansas," Senate Document No. 282, Government Printing Office, Washington, 1902.

ART. XVIII.—*On the Genesis of Riebeckite and Riebeckite Rocks*;* by G. M. MURGOCI, Bucharest.

RECENT investigations have shown that riebeckite rocks are not uncommon; new occurrences are being discovered, and in old localities alkali rocks described as containing black or blue hornblende are often identified as really containing riebeckite. These rocks are attracting special attention, because of the presence of this rare sodium-iron amphibole, and because some of them are the most acid of alkali rocks, rising to 78 per cent in SiO_2 (according to the analyses of Butureanu, Ludwig, etc.) and to 10 per cent in Na_2O and K_2O .

I have discovered these interesting rocks in Dobrogea at Jacobdeal and Piatra Rosie \u0162 (at the mouths of the Danube), and was able to study *in situ* their geological characters and relations to the enclosing rocks. I have also compared them in the laboratory with similar rocks from other localities. A r sum  of the facts in Dobrogea is as follows:

In the Paleozoic formations composed of quartzites, sandstones and conglomerates, calcareous and argillaceous shales and crystalline limestone, the following rocks are found as intrusive masses: various kinds of granites, microgranites, quartz and orthoclase porphyries, diorites and olivine gabbros, etc., which in general occupy the anticlines of the sedimentary formations. All the foregoing rocks and the Triassic sandstone and limestone are penetrated by dikes of microgranites, porphyries, diorites, pearl and porphyritic diabases, etc. It has been proved satisfactorily that there have been two epochs of volcanic activity: Paleozoic (pre-Permian) and Triassic. Sometimes the mesocratic rocks of the two series are very similar and could easily be confused one with another, if the field relations are not correctly interpreted.

The rocks of the first volcanic epoch, usually alkali rocks (Mrzecz), show a consanguinity obvious in the field and confirmed by investigation in the laboratory, Dobrogea being in this respect a very interesting petrographical province. Riebeckite rocks, however, are confined to the hills of the western Dobrogea in two of the anticlines of the slightly metamorphosed argillaceous shales and sandstones. The anticlines have a northwest-southeast strike and in the region of Carjelari run

* Preliminary communication read before the Geological Society in Philadelphia, December, 1904.

† G. M. Murgoci, *Ridic ri geologice* in N. Dobrogei, Bull. Soc. Inginerilor de mine, 1898, Bucuresti.

Among the specimens that I collected in the quarries of Jacobdeal, Prof. L. Mrzecz recognized riebeckite granite and described it in: *Note preliminaire sur un granite   riebeckite and  ezirine des environs de Turcoaia* (Dobrogea). Ibidem. 1899.

together, forming, by their uniting cores, one single large mass of eruptive rocks.* In this zone, granites (soda-granites, nordmarkite, and quartz syenite) microgranites and granite porphyries (granophyre and paisanite) and typical quartz and orthoclase porphyries are found together in the same or neighboring localities. One may remark, according to the present exposures and topography of these rocks, that the porphyritic masses, with or without riebeckite, occupy a larger area at the surface than the granite (in the proportion of 3:1); the region is much eroded, the layers are almost vertical and the porphyritic facies occurs in the western part of the granite zone. In this case the porphyritic rocks can not be regarded only as marginal facies of the granite massif. On the other hand, the various rocks with riebeckite form large streaks and patches (*schlieren*) mixed at random in the massives, with similar masses without riebeckite, but very acid and poor in black constituents. Some masses, especially those of more basic character, were obviously homogeneous and polygeneous inclusions. Although there are many quarries in the two hills of Jacobdeal and Piatra Rosie, which furnish exposures, dike rocks of pegmatitic, aplitic or lamprophyric characters could not be found. In one place a rock of the type of nordmarkite occurs in such a manner that it might be regarded as a dike terminating abruptly upwards; the same rock, however, occurs in the neighborhood as polygeneous inclusions.

Owing to the absence of obvious dikes, it is impossible to determine the order of the ascension and consolidation of the magmas forming these various rocks. Their occurrence and structure, their study by chemical and petrographical methods and the relations between them, reveal to us only local phenomena which occurred during the consolidation of the large molten mass.

It is well known what a tendency the alkali magmas have to differentiate and especially in massives of sodic rocks; this fact can be very well confirmed, as shown by numerous researches. This phenomenon, often described in the alkali rocks of the trachyte-syenite series (especially in nephelite syenites), is also mentioned in massives with riebeckite rocks of the granite-rhyolite series, when studied over large areas. There might be cited the classic researches by Brögger (Christiania region), Tenne (Yemen), Washington (Essex County, Mass.†), Lacroix

* See the geological map by R. Pascu, *Moniteur du Pétrole roum.* 1904. Bucharest.

† In the neighborhood of Boston, "the glaucophane granite" studied by White has been determined by Washington as riebeckite granite (*Journal of Geology*, vol. vi, No. 8 and fol., 1898-1899), and among the specimens which I possess through the kindness of Prof. Kemp, I was able to distinguish riebeckite granophyre, paisanite, interesting inclusions, etc. Even White described gradual variations of structure and composition in one and the same massif. *Proc. of the Boston Soc. of Nat. Hist.*, 28, No. 6, 1897.

(Madagascar, Corsica, Colorado), Pelikan (Socotra, etc.), Harker (I. of Skye, etc.), and many interesting remarks in Rosenbusch's writings, where he discusses amphibole and pyroxene granites, etc. The very interesting example is given by Lacroix* in the rhyolite of Somalis, where schlieren of microgranite were observed in the rhyolitic mass.

I have recently compared my riebeckite rocks with those from Scotland, Wales and Massachusetts, and have been able to extend and generalize the conclusions of Lacroix† deduced from observations on different granites with riebeckite and ægirite, and I would include also microgranitic and porphyritic types from granite and quartz syenite series. Summarizing the observations, we may emphasize the characters which reveal to us the genesis of the riebeckite rocks as follows:

1. The massives with riebeckite rocks are characterized by a great variety of types rich in soda as schlieren or as dikes. In such massives there is very frequently a tendency towards a pegmatitic or miarolitic structure in some of the schlieren, and a fluidal or microgranitic one in others. Schlieren with a protoclastic structure may be observed in the holocrystalline types and also in porphyritic ones.

2. Variations occur not only in the structure, but also much more in the constituents, especially in the dark-colored ones, which are, however, almost always amphibole, or pyroxene, or both, often grown together or zonal. The amphibole in the most acid rocks is of the arfvedsonite-riebeckite group, in the relatively basic ones it is of the kataforite-barkevikite group; the pyroxene is ægirite or ægirite-augite. Ægirite nearly always accompanies riebeckite; but while ægirite occurs often as well developed, more or less idiomorphic, crystals, the large patches of riebeckite have, as is well known, a spongy, poikilitic structure with a well marked allotriomorphic development. The character of its occurrence, in even granular rocks and in porphyries, shows that riebeckite has been formed continually during the whole time of the consolidation of the magma. It is found as microlites, in small and minute prisms and needles or fibers, included in other constituents such as feldspar, quartz, etc.; as large dark-blue crystals grown together with other minerals, such as ægirite, zircon, and pyrochlore; as patches cementing feldspar and even quartz; as poikilitic shreds and beads in the groundmass of the porphyritic rocks; further it is found in miarolitic cavities, in pneumatogeneous inclusions, in the cracks and druses of the rocks filled by pegmatitic masses, etc.

* A. Lacroix, *Les Rhyolites à ægirine and riebeckite de Somalis*. C. R., Ac. Sc. Paris, cxxviii, 1899.

† A. Lacroix, *Matériaux pour la Minéralogie de Madagascar*. *Nouvelles Archives du Muséum d'Hist. Natur.* IV^e s. 1902, p. 164, etc. See also *Les travaux de M. A. Lacroix*, 1903.

3. The riebeckite rocks represent in the massives the pegmatitic varieties, consolidated under special physical conditions, riebeckite being a mineral which requires pneumatolitic conditions for its formation. All petrologists, who have studied riebeckite rocks, mention pegmatitic, micropegmatitic or granophyric structures as being characteristic of them. Brögger* has remarked that riebeckite (and arfvedsonite) occurs especially in rocks rich in quartz (over 60 per cent, according to the analyses of Butureau† and E. Ludwig‡, up to 78.5 per cent), and on the other hand, while ægirite occurs in almost all the rocks of the Christiania region, riebeckite appears only in those which indicate high pressure, and is wanting in those pegmatitic dikes, where ægirite is the most frequent mineral. Flink & Böggild§ have described riebeckite ("type II of arfvedsonite," Riebeckite?) in the pegmatitic schlieren of Greenland (Narsarsuk), which are also very rich in ægirite. It must be noted, that the syenite pegmatites of Narsarsuk occur not as veins or dikes, like those from Christiania, but "there are dike-like syenite formations, which differ from the ordinary typical syenite, in having as chief elements constituents, rich in iron, of the pyroxene and amphibole series. There can be no question of dikes or deposits, . . . the minerals show that the pegmatitic formations have arisen simultaneously with the bulk of the rock." Heddle, Prior, König, etc., have also studied perfect crystals from quartz dikes or miarolite cavities only. On the other hand, Lacroix|| has described very characteristic pegmatites, containing the only large crystals of riebeckite known, which come from Colorado (San Petro's Dom), Corsica, Madagascar, etc. The riebeckite crystals occur in the pegmatite-like black tourmaline in common pegmatites; the riebeckite pegmatites pass over gradually into granitic or microgranitic rocks.

* W. C. Brögger, *Eruptivgesteine der Kristiania Gebietes*, i, 1894, pp. 36, 39, 184, 186, etc.

† V. Butureau, *Sur la composition des granites à Riebeckite de Jacobdeal, Dobrogea. Annales scientifiques de l'Université de Jassy*, 1893. An analysis of riebeckite too.

‡ A. Pelikan, *Petrographische Untersuchungen von Gesteine der Inseln Sokotra, Abdel Kâri und Semba. Denkschriften der Math. Naturw. Klasse der k. Akademie Wien*, 1902, lxxi. Analyses by Prof. E. Ludwig.

§ J. Flink, O. Böggild and Chr. Winter. *Untersuchungen über Mineralien von Julianehaab. Meddelelser om Groenland*, 1899, 24. Reference in *Zeitschr. f. Kryst. and Min.* xxxiv, 1901.—N. v. Ussing (*ibidem*, 1894, Abstract in *Neues Jahrbuch f. Miner., etc.*, 1901, 45) cites riebeckite also in syenite.

|| A. Lacroix, after the communications to Académie de Sciences, Paris (Colorado, *Comptes Rendus* cix, 1889, Mt. Saber, C. R. cxxviii, 1899) returns to the Corsican rocks (described first by Le Veir, C. R. cix, 1899, and Nentien, *Mem. carte géol. France*, 1897) in *Minéralogie de la France*, i, 695, and recently discusses the general question in *Matériaux pour la Minéralogie de Madagascar. Nouv. Archives du Muséum d'Hist. Natur.* 1902–1903. See also: *Les travaux de M. A. Lacroix*, 1903.

4. I may further emphasize the similarity of riebeckite, in its occurrence and petrographic characters, with the tourmaline from tourmaline granites, aplites, etc. The poikilitic structure of the large crystals, hypidiomorphic and allotriomorphic forms in one and the same rock, are characters common to both riebeckite and tourmaline. The rocks with tourmaline are very alkalic like those with riebeckite*; riebeckite like tourmaline eliminates other black constituents such as biotite. The riebeckite rocks have their special accessory mineral, zircon, in the same way that tourmaline rocks carry cassiterite.†

5. The quartz and the feldspars (which are orthoclase either with patches of soda-microcline or with albite in micropertthite intergrowths, all more or less idiomorphic) contain many inclusions of riebeckite, zircon, and liquids with bubbles and cubes of common salt.

6. A great deal of zircon accompanies the riebeckite; Brögger, Washington, Mrazec, Lacroix and Souza Brandão (1905) emphasize this fact. Lacroix found as much as 7·5 per cent zircon in the rocks of Madagascar. The barkevikite rocks, on the other hand, contain much titanite. It is worthy of mention in this connection that Brögger‡ states that in the middle of a dike of quartz-lindöite (of west Aker, Christiania) riebeckite occurs with much zircon, crystallized after riebeckite, whilst at the salband there is katoforite and ægirite without zircon; on the other hand, zircon is very frequent in the pegmatitic dikes at the Christiania region. Zircon and titanite have been formed during the whole time of the consolidation of the magma-like riebeckite.

7. In miarolitic cavities of these rocks fluor spar, galena, zircon (spinel?) and riebeckite have been found together. Brögger, Lacroix and Washington state that fluor spar is often a constituent of the rocks rich in soda, which contain ægirite and riebeckite, and in general I have also found it in many of the rocks of the region studied by me and in those of other places, such as in the Quincy granite, the trachyte of Berkum near Remagen, the microgranite of Ailsa Craig, etc.

The occurrence of fluor spar in certain granites is very important from a theoretical standpoint; in them fluor spar occurs as small crystals, often microlites, grown together with or included in the ægirite; riebeckite when inter-grown with ægirite is quite free from such fluor spar inclusions, but may contain small pockets of rare carbonates (parisite?). In general

* The complicated composition of riebeckite is well known. I know of six analyses and no two alike; the differences can not come from mistakes only. On the other hand, riebeckite contains Fl also.

† A. Lacroix, *Matériaux de Madagascar*, loc. cit., 1, p. 89.

‡ W. C. Brögger, loc. cit., pp. 137, 138.

ægirite granite carries much fluorspar; in the pure riebeckite granite, on the other hand, it is almost entirely wanting. Brøgger* mentions the occurrence of much fluorspar and ægirite on the salbands of the grorudites of Omholtsaeter, which are apophyses of the soda-granite of Kongsberg and in relation with the genuine pegmatitic dikes and akmite granite of Rundemyr. According to Rosenbusch† in this massif there occurs also riebeckite granite.

Brøgger‡ described also a peripheral transformation of barvikite into ægirite and lepidomelane with a rich accompaniment of fluorspar, and he explains this change as due to pneumatolitic action at the end of the consolidation of the hydato-pyrogenous mass or immediately after it. This may be possible in the pegmatitic dikes of Christiania, where Brøgger has proved four phases of pneumatolitic action, ægirite being formed in the third phase. If the rock contains both riebeckite and ægirite, often grown together with fluorspars and carbonates, I believe the process to have occurred in another manner, riebeckite and ægirite being primary, fluorspar and carbonates also. It is well known what complicated relations of zonal and other intergrowths there are between the pyroxenes and amphiboles when they occur together, especially in ægirite-riebeckite rocks; some petrologists have considered the ægirite as a transformation product of riebeckite, and others have taken the riebeckite for a secondary product of ægirite. Among other examples there might be mentioned the one furnished by Cross§ in his description of amphiboles from Silver Cliff, Col., and another by Böggild (loc. cit.), who has found in the pegmatitic schlieren of Narsarsuk arfvedsonite covered by secondary ægirite, and in the same rock riebeckite with a core of ægirite. Most petrologists state, however, that riebeckite and ægirite are primary in their rocks. Without denying the later transformation of riebeckite into ægirite, a fact easy to imagine considering that their composition is similar and that ægirite seems to be the more stable form, I believe, however, that in general riebeckite and ægirite are both primary in rocks, and if transformations have taken place, they must have occurred before the consolidation of the magma.

The genesis at the same time of these two minerals of almost identical composition is a very interesting phenomenon and deserves to be taken for a moment into consideration: Steen-

* W. C. Brøgger, *ibidem*, p. 190.

† H. Rosenbusch, *Massige Gesteine*, II ed., p. 59.

‡ W. C. Brøgger, *Die Mineralien der Syenit-pegmatitzänge von Norwegen*. *Zeitschrift der Krystallographie und Mineralogie*, 16, 1890. The first part is devoted to the rocks of that region.

§ Whitman Cross, Note on some secondary minerals of the amphibole and pyroxene groups. *This Journal*, xxxix, 1890.

strup* by melting arfvedsonite has obtained aegirite; Doelter by melting gastaldite in sodium fluoride has also obtained aegirite or akmite, but without fluoride there resulted an amorphous mass. These two experiments and many others have shown that aegirite and pyroxene can originate in molten masses under ordinary conditions. This is, however, not the case with amphiboles, and recently Vogt† has demonstrated again that amphiboles require high pressure for their formation. Considering the facts more closely, for a medium to be capable of giving rise to the riebeckite or aegirite molecule (which may be expressed by $\text{Si}_4\text{O}_{11}\text{Fe}'''\text{Fe}''\text{Na}_2\ddagger$), there appear to be two chief factors necessary, namely *pressure and mineralizers*§. The obvious fact that these two minerals can originate at the same time in a magma, shows that there cannot be much difference between their coefficients of solubility, i. e., their capacity for forming saturated solutions in the molten mass; on the other hand, the melting point of these minerals (aeg.=940°, rieb.=945° C. according to Doelter) is not different under ordinary circumstances and cannot vary much if the circumstances vary in the same way for both minerals. The structure of the riebeckite-aegirite rocks and the mode of occurrence of these minerals support the statement of Höpfner verified by Vogt (l. c.), that pressure has not much influence on the order of separation of the minerals in a magma and on the composition of eutectic mixtures. I may add, with respect to the ideas of Loewinson-Lessing,|| that pressure alone is not sufficient to force a dimorphous substance to crystallize in one form rather than in another, although one may have a smaller true molecular volume than the other. According to this general dynamic rule, aegirite, with the smaller molecular volume, should be the characteristic mineral of the abyssal rocks rich in soda. Observation and experiment contradict this: aegirite can form under ordinary pressure and occurs much more in hypabyssal and volcanic rocks than in abyssal ones; riebeckite has not been obtained at ordinary pressure, but it occurs in trachyte with fluorspar and in rhyolites, which clearly show evidences of a pneumatolytic process. On the

* The best argument for the primary existence of the aegirite is its occurrence, in the same rock, with little thin needles of riebeckite, which could not resist even the slowest and slightest action of transformation.

† T. H. Vogt, Die Silikatschmelzlösungen. Mem. of the Acad. of Christiania, 1904.

‡ This formula given by König, and confirmed by Butureanu on the Dobrogean riebeckite, agrees very closely with the analyses of aegirite by Doelter.

§ This question in particular I intend to take up again, after some experiments, with more detail.

|| F. Loewinson-Lessing, Studien über Eruptivgesteine. Memoires du Congrès Geol. de St. Petersburg, 1897, p. 325 f.

other hand, the schistose metamorphosed riebeckite rocks of Gloggnitz and Alter Padroso, etc., show no transformation in this respect, ægirite and riebeckite having the same character and both being primary, often grown together or zonal, as in the unpressed eruptive rocks. We are forced accordingly to invoke, besides the composition of the magma and the pressure, also that important agent, which has left its traces in the components of these rocks, the *mineralizers*.*

If now, p represents the conditions of pressure, which may be unity, or one atmosphere, and m the mineralizers†, which may be much reduced, of a magma in which the whole substance $\text{Si}_2\text{O}_3\text{Fe}''', \text{Fe}''\text{Na}$, may crystallize as ægirite, then P and M may be the conditions of minimal pressure and mineralizers in which the same substance may crystallize as riebeckite. One can imagine that between the points p, m and P, M there may be a large number of stages (P_x, M_y), where there can arise a variable percentage A of ægirite to R of riebeckite, more or less respectively, accordingly as a particular stage is nearer to the point p, m or P, M .‡ The variation of the medium μ (composition of magma + mineralizers) influences in large proportion the phenomena, and the representative curve of the phenomena $f'(m, p)$ is displaced in plane, and for a definite value of μ we meet with a critical point for the formation of riebeckite; in a magma below this limit,—riebeckite can no longer form under any pressure by the given mineralizers. And according to these different conditions of a magma, pressure and mineralizers, there can originate in one and the same igneous mass and at the same time of consolidation rocks with riebeckite only, rocks with riebeckite and ægirite in all proportions, and those with ægirite alone.

In this way we can explain the relations which have been observed between riebeckite, ægirite and fluorspar. The min-

* F. Loewinson-Lessing in his interesting discussion (l. cit. p. 359) admits the necessity for pressure and an active gas (he means water) for the formation of amphiboles. The experiments which he has made by melting pyroxenes and amphiboles in an atmosphere of water vapour have not been successful in producing hornblende. It would be very interesting to know what would be the result of an experiment in a fluorine atmosphere under a high pressure! I may note that the only synthetic hornblende (with $2\frac{1}{2}\text{Na}_2\text{O}$) was obtained by Chrustachoff (1891) in sealed tubes in the presence of water at high temperature.

† That is to say, the capability of the mineralizers for forming minerals.

‡ This question is a very complicated one and we do not know how many substances and how many phases there are at a given moment. We may, however, imagine the simplified case of n substances (magma, iron-sodium silicate and fluorine mineralizers) and $n+1$ phases (magmatic solution, riebeckite, ægirite and gas). The most analogous example is to be found in the crystallization of calcite and aragonite (or conchite) from a dilute solution at varying temperatures. See: Beiträge zur mineralogischen Kenntnis der Kalkausscheidung im Tierreich von Agnes Kelly. Jenäischer Zeitschrift für Naturwissenschaft, 1900.

eralizers have not a catalytic action only; it has been demonstrated several times that they have an active part in the consolidation of magmas and in the formation of minerals. Accordingly, in a magma of a definite composition containing mineralizers and under a sufficient pressure to give rise to riebeckite, a part of the mineralizers (F1, Na, Ti, Zr, etc.) play an active rôle in the formation of the riebeckite, entering also into its composition.* Where there is low pressure and the mineralizers are not appropriate for the formation of riebeckite, ægirite is formed, and the mineralizers, which it does not require for its production, react on the magma and among themselves, giving rise to other characteristic minerals with the form and paragenesis which we have seen above.

8. The former presence of high pressure and abundant active mineralizers can be clearly deduced from the study of riebeckite rocks, as may be seen from the works of Brögger, Lacroix and others. Lacroix, in particular, concludes from the presence of fluorspar, galena, zircon, and the pseudomorphic changes and alterations undergone by riebeckite and ægirite, that emanations characterized by fluorine and zirconium were active at the moment of consolidation, and that in riebeckite rocks zirconium plays the part of tin in alkali rocks with tourmaline. He, like Brögger, assumes a powerful manifestation of post-volcanic activity, which in some cases has produced deposits of cryolite, as at St. Peter's Dome, Colo., and in Greenland, or marked transformations in the structure and composition of the rocks, as in the rhyolite of Somalis.

According to my researches in Dobrogea the post-volcanic activity is almost wanting in massives with many schlieren and much variation in the kinds of rocks. No pegmatitic dikes or veins like those in Greenland or Norway have been seen in the many quarries in Jacobdeal and Piatra Rosie, and the contact metamorphism of the neighboring rocks is very small. I may add that, in this respect, the alkali granite of Măcin and Pricopan shows much greater contact phenomena and pneumatolitic post-volcanic activity. In the cracks of the Jacobdeal granite I have found only a few spots coated with little crystals of quartz, hæmatite, very rarely fibers of crocidolite, and beautiful dendrites of ferromanganese hydroxides like those from the Quincy granite.

* This deduction finds a certain verification in the composition of riebeckite; unfortunately the existing analyses are very unsatisfactory. In a recent conversation with Dr. Tassin, he informed me that he had found fluorine in a riebeckite which he is analyzing. Amphiboles with fluorine are known; for example, see the pargasites, etc., in the table of analyses by Hintze, and the hornblende from Grenville (Quebec) with 2.8 per cent F1 (Harrington, B., this Journal, 1903, p. 392). Perhaps the loss in König's (riebeckite) analyses (made, he says, with all precautions) may be fluorine.

The pneumatolitic elements have been in the magma and reacting rather during the time of the consolidation of these riebeckite rocks than later (as I have attempted to show above). The study of the inclusions of riebeckite granite give further support for this statement. Such inclusions have been mentioned by Brögger, Washington, and White, but do not seem to have aroused much interest. I have found many inclusions in the granite of Jacobdeal and Piatra Rosie, and have observed some in the Quincy granite. They may be classified as follows:

Homogeneous inclusions, that is aggregates of riebeckite which are often fibrous (crocidolite?), with spongy quartz, zircon and hematite; the riebeckite forms large prisms but is not well developed.

Pneumatogeneous inclusions, that is, those formed by mineralizing vapors which are porous or hollow, with a great deal of fluor spar, galena, pyrites, pyrotite, mispickel, hematite and many earthy looking minerals which are certainly alteration products of other minerals; riebeckite and augite-ægirite are rare, feldspar is more frequent and there is very little quartz.*

Polygenous and enalogenous inclusions formed by varying combinations of processes, of variable size and composition; in such inclusions occur large crystals of orthoclase and albite, pyroxenes, amphiboles (but no riebeckite), astrophillite, mica, etc. Through the assimilation of these inclusions local variations in the composition and structure of the granite arise, and rocks are formed (endopligenous inclusions) of the types of nordmarkite, akerite, grorudite, paisanite and even quartz-pulaskite and sölvebergite. The occurrence of these different rocks as inclusions is very striking in the many quarries of Dobrogea and also in specimens from Quincy, Mass†. In many of these rocks riebeckite is replaced by katoforite or barkevikite, and this fact can be explained, in my belief, by variation in the composition of the magma under definite limits, while pressure and mineralizers remain the same as in the main mass.

Lacroix has described from Ampasibitika contact rocks of a riebeckite granite (perhaps in part inclusions) and states that they contain the same minerals, riebeckite—sometimes in pseudomorphic forms—ægirite, fluor spar, spinel and zircon, which occur in the granite. The contact of Dobrogea does not show marked metamorphism; there are epidote, pyroxene and amphibole hornfelses, but without riebeckite, and it may be

* G. Murgoci, Minerale din Dobrogea. Publicatiunile Soc. Naturalistilor, 2, 1902. Bucharest.

† I may further remark that the analyses of an enclosure in granite of Pigeon Hill, by Washington (loc. cit.), does not differ at all from the akerite analyzed by the same investigator. Journal of Geology, 1898-99.

added that in general this mineral does not occur in genuine schists. The well known forellengranulite (orthogneiss) of Gloggnitz,* the riebeckite granulite of Alter Pedroso in Portugal,† are surely eruptive rocks,‡ and their characters are quite similar to those summarized above. Lacroix§ mentions genuine schists with riebeckite from Corsica, from the Alps of Savoy, from Bulgar Dag in the Taurus, etc., which occur associated with glaucophane schists. It is to be noted that the riebeckite of these rocks occurs as needles and fibers, radially spherulitic or lenticular, and it has always been compared with the tourmaline of luxullianite. In some rocks, especially holocrystalline ones, needles and fibers of riebeckite(?) are found in such relation to large crystals of riebeckite or ægirite, that they look like secondary products and are quite similar to those described by Cross, Lane, White and Washington. Cross has identified the blue amphibole of Silver Cliff with the crocidolite of Lacroix||; perhaps it is the case that all these kinds of blue amphiboles should be referred to crocidolite.¶ Crocidolite seems to be different from riebeckite both in occurrence and composition; its genesis in riebeckite rocks seems to show that it should there be primary, indicating circumstances which Weinschenk presupposes in piezocrystallization; and many characters of crocidolite are in accordance with this hypothesis, as S. Franchi has deduced for the glaucophane (and crocidolite) schists.

From the above mentioned characters of riebeckite and of the rocks in which it occurs, we may, to some extent, deduce the circumstances under which these rocks have been formed, especially those from Dobrogea.

The magma which has given rise to the riebeckite rocks ascends from an alkaline magma basin, from which it is derived by a process of magmatic differentiation. The molten mass,

* H. Keyserling, Der Gloggnitzer Forellenstein: Tschermak's Mineral. petrogr. Mittheilungen, xxii, 1908.

† V. de Souza Brandão, Ueber einen portugiesischen Alkaligranulit. Centralblatt für Mineralogie, Geologie und Paleontologie, 1902, p. 50.

‡ Dr. Teall and Fleet have found, last summer, in Wales, a riebeckite gneiss which in mineralogical and petrographical characters seems a granite gneiss.

§ A. Lacroix, Mineralogie de la France, i, p. 697.

|| With the blue amphibole described by W. Cross, C. Palache has identified another blue amphibole, *crossite*, from an albite schist of Berkeley, Bul. of Geol. Depart. Calif. Univ., i, 1894. I may observe, however, following the comment of Lane and my own determinations, that this cannot be done; the crossite of Berkeley is a blue amphibole (glaucophane) which has the plane of the optic axes perpendicular to (010), $b:c=16''$. But I have found the amphibole of Cross in a aenite from Spanish Peak, Cal., and it looks like crocidolite.

¶ S. Franchi, Prof. Louderback. etc., have found crocidolite quartzite in the area of glaucophane schists which are very similar to the riebeckite schists described by Lacroix.

isolated perhaps in an anticline or in a laccolith, is maintained for a long time as a mother liquor in a state of hydrothermal fusion in which there swim crystals already formed, or in process of formation. On account of the impermeability to vapor of the beds of shale, quartzite, etc., between which it has been introduced, the mineralizers cannot escape, they continue to act on the magma and to be gradually assimilated. The presence of fluor spar, zircon, titanite, and sulphides as constituents of the riebeckite rocks, the occurrence of pneumatogeneous and polygeneous inclusions and of schlieren with characteristic minerals confirm this view.

The chief factors in the formation of riebeckite rocks are the pressure and definite mineralizers; with the variation of these two factors and of the composition of the magma, the products of crystallization are also changed. Only under high pressure due to tectonic movements and to the persistent retention of mineralizing vapors, and with a large quantity of the latter present, could riebeckite be formed; if one of these factors varied, especially the pressure, ægirite would then occur in addition to riebeckite. Of course the pressure, the mineralizers and the composition of the magma usually differ from one point to another, as may be seen from the quantitative and qualitative variation of the mineral elements of the rocks. Especially had the assimilation of inclusions of neighboring rocks provoked such variations of chemical and physical conditions, that riebeckite could no longer be formed.

In addition to the chemical, a mechanical action was present; new upwellings of fluid magma and of mineralizers cause streams and vortices in the consolidating molten mass. These influence the crystallization and aid in the formation of schlieren; in the more quiet parts a pegmatitic or a granular structure is produced; there in the streams and more agitated areas a fluidal or a protoclastic structure originates; the rapid sinking of the temperature, the loss of mineralizing vapors, or lowering of pressure in other parts, determines a porphyritic structure with the two periods of consolidation more or less well pronounced of the mineral constituents.*

Riebeckite forms only in the relatively most acid magmas, and especially under the influence of mineralizers: its composition, content of fluorine, long period of crystallization from the beginning up to the end of and even after the consolida-

* In respect to the conception of the rôle of the mineralizers and inclusions, their influence at the time of consolidation of the magma, the forming of schlieren and of the structure, I incline toward the views of the French petrologists. None the less, in the ideas of Prof. E. Weinschenk I have found many points à propos to these views; the short and clear chapters on these questions in his book, *Gesteinskunde I*, 1902, excite my heartiest admiration.

tion of the magmas; its occurrence in cavities and its paragenesis with zircon, pyrochlore, fluor spar, sulphides, etc.; its presence as large crystals in pegmatites in immediate relation with veins of fluor spar or cryolite, and its absence in non-eruptive rocks, are many facts which support the view as to its origin presented in this paper.

The mineralizers which aid to produce it are not rich in water and sulphur vapors, but are characterized by an abundance of Zr, which has played a part in riebeckite granite similar to that of Sn in cassiterite granites. Zircon also forms throughout the whole period of consolidation. One can correlate: tourmaline—Sn; riebeckite—Zr and katoforite (or another soda amphibole)—Ti.

The magma has been fairly rich in Al_2O_3 , Na_2O , and K_2O , but a large quantity of soda and iron have been brought in by mineralizers and the genesis of riebeckite facilitated. The occurrence of masses and small areas of hæmatite and limonite, around or across the inclusions and schlieren, does not come from secondary alteration, but from areas which at the moment of consolidation were still more or less impregnated with iron compounds and water vapors.

Doubtless new upwellings of magma and of mineralizers have caused some transformations in the minerals already formed in the riebeckite and ægirite, but needles and fibers of crocidolite could be formed in eruptive rocks, as well as in metamorphic schists, as a phenomenon of piezocrystallization, which is quite in accord with the process which I have here tried to sketch.

ART. XIX.—*Purpurite, a new Mineral*;* by L. C. GRATON and W. T. SCHALLER.*Introduction.*

IN the central portion of the Carolinas there occurs a belt of metamorphic rocks penetrated by narrow dikes of pegmatite, many of which contain lithium minerals. There can be little question but that the dikes of pegmatite represent the final product of a parent magma which has crystallized as granite and appears almost continuously along the extent of this belt.

Attention was first directed to these pegmatites by the discovery of cassiterite in them. In the autumn of 1904, one of the writers made an examination of these tin deposits for the U. S. Geological Survey. During the course of this study, Mr. J. L. Daniels, superintendent of the Faires tin mine at Kings Mountain, Gaston County, N. C., called attention to a purplish material encountered within a few feet of the surface in the workings of that mine. Thanks are due to Mr. Daniels, who kindly supplied much of the material obtained. Preliminary examination failed to identify the material with any known mineral, although its properties seemed to be those of a definite crystalline compound. Chemical analysis shows that the material is a new mineral, being a hydrous manganic ferric phosphate—the only manganic phosphate known.

The most striking feature of this mineral is its purple or dark reddish color, and for this reason it has been named *purpurite*, from the Latin *purpura*, purple or dark red.

Since the discovery of this mineral in North Carolina, the same mineral has been noticed on some specimens from San Diego County, California. These had been collected by one of the writers, and through the courtesy of Mr. F. M. Sickler, of Pala, several more specimens from this locality have been obtained. They are from one of the lithium-bearing pegmatite dikes on Hiriart Hill, Pala, San Diego County. The mineral occurs with triphylite, and possesses the same purple color as the North Carolina specimens. Under the microscope, the appearance and properties of the mineral from the two localities are identical. There is, however, not enough of the California material for chemical examination.

Occurrence and Physical Properties; by L. C. GRATON.

The mineral purpurite is found in small irregular masses in the tin-bearing pegmatite dikes, and in the near-by schist at the Faires mine. In most cases it occurs in narrow lenses or

* Published by permission of the Director of the U. S. Geological Survey.

veinlets, and appears to have been deposited from solution in cavities. Occasionally, however, it is found in the midst of the pegmatite as if it were an original mineral.

The question of the origin of purpurite is one of interest. Pegmatite dikes believed to be closely related to the tin-bearing dikes carry the rare-earth phosphate, monazite. Among the primary minerals of the tin-bearing pegmatites are cassiterite, tourmaline, apatite, spodumene, lepidolite, and a yellowish brown, lithia-bearing phosphate which is doubtless lithiophilite. The last two minerals have been found only in small quantities. Partially decomposed specimens of this pegmatite frequently show much manganese dioxide as thin mammillary coating on the other minerals. Ilmenite is often included in crystals of cassiterite. It is evident, therefore, that the elements manganese and iron (as monoxides), lithium, and phosphorus (as phosphate) were primary components of the pegmatite magma.

The mineral presumed to be lithiophilite is always surrounded by a coating of black, secondary material. In one case, a narrow zone of purpurite was found between the lithiophilite and the black mineral. It is believed that this single occurrence furnishes the explanation of the origin of purpurite. A lithia-manganous-ferrous phosphate, probably lithiophilite, was attacked by oxidizing solutions. The lithia was almost wholly carried away, while of the remaining elements, iron and manganese were oxidized to the state of sesquioxides and were recrystallized with the phosphoric acid and water to form purpurite. The trace of lithium which this mineral contains is a remnant of that from the lithiophilite. In some cases the recrystallization took place without transportation of the materials, forming pseudomorphous replacements, but in general the materials were carried in solution to cavities and there deposited.

Purpurite is probably orthorhombic, but no specimens have been found which show crystal outline. A cleavage which is probably pinacoidal is of rather perfect development, but the cleavage surfaces are often curved as if the orientation of adjoining grains were not exactly the same. A second cleavage, presumably at right angles, is considerably less distinct. The mineral has an uneven fracture and is rather brittle. It is scratched without difficulty by the knife, but on the other hand just scratches fluorite, and hence has a hardness of 4-4.5. Mr. Schaller determined the specific gravity as approximately 3.15. In color the mineral is a rich deep red or reddish purple, sometimes with a slight bronzy iridescence, and not uncommonly darker on the cleavage planes. The powder and the streak have a decided purple or deep rose color. The mineral has a peculiar satiny luster or sheen, more noticeable on fracture surfaces than on cleavage planes.

Although transparent in very thin pieces, the ordinary thin section allows the passage of very little light through purpurite. The colors in transmitted light are very beautiful. Pleochroism is noticeable. Parallel to the cleavage the color is a deep scarlet, inclining to rose-red, while across the cleavage the absorption is greater and the color becomes a beautiful purple. This absorption, it will be noticed, is similar to that of tourmaline and a few other minerals, in which the greatest absorption is at right angles to the direction of cleavage or elongation. Extinction is generally parallel; an inclination up to three or four degrees, which has been observed in a few instances, has probably been due to the orientation of the sections examined. It may be, however, that the mineral is monoclinic, with a very small extinction angle. Sections which were transparent were not of sufficient size to give an interference figure. No sections showing the intersecting cleavages were seen, and in all the sections examined the traces of the cleavages are parallel to the direction of greater elasticity of the section; so if the mineral is biaxial, the intersection of the cleavages is parallel to a . This is also the direction of least absorption. The refractive index is somewhat greater than that of Canada balsam and probably lies between 1.60 and 1.65. The difference of the indices or the double refraction is high, and although it could not be measured at all accurately, is probably not much below .060. One effect of this high double refraction on the very thin sections examined is that under crossed nicols the mineral appears to transmit as much and as brilliant light as without polarization. The red interference colors are very striking.

The purple mineral is always covered or surrounded by a greater or less thickness of a black or brownish black material of pitchy luster and uneven or sub-conchoidal fracture. This material, which is soluble in hydrochloric acid, has been found by Mr. Schaller to contain iron, manganese, phosphoric acid, and water. Under a lens the black material can be seen to encroach upon the purpurite, eating in along the cleavage planes and gradually replacing the purple mineral. It is undoubtedly a decomposition product of purpurite and is certainly the same as that which surrounds the supposed lithiophilite. Viewed with the aid of the microscope it appears to be a definite mineral, having an imperfect cleavage, and a brownish yellow color in transmitted light. Extinction is nearly or quite parallel to the cleavage, and the trace of the cleavage is the direction of least refractive index of the sections examined. Pleochroism is distinct and, as in the case with purpurite, absorption is greatest across the cleavage. The index of refraction is greater than that of Canada balsam, and the double refraction

tion is probably rather high. It is hoped that sufficient of this material for analysis will soon be obtained.

The occurrence of purpurite in material collected from California by Mr. Schaller throws additional light on the origin and association of this mineral. It occurs with a black material which appears to be identical with that described above, and both are undoubtedly decomposition products of the accompanying triphylite, the iron-rich member of the lithia-manganous-ferrous phosphate series, of which lithiophilite is the manganese-rich end.

The small number and rarity of minerals containing manganic oxide, Mn_2O_3 , may be due to the relative instability of that base in comparison with manganese dioxide.

Chemical Composition ; WALDEMAR T. SCHALLER.

About a gram of pure material was separated by Mr. Graton. This was divided into several portions, using about a fifth of a gram for each determination. The most interesting part of the analysis was to determine the state of oxidation of the manganese. When the mineral is treated with hydrochloric acid, chlorine is readily given off. The manganese present can therefore not be in the manganous state, and the absence of ferrous iron and the presence of ferric iron suggested that the manganese was present as a manganic salt. Such was found to be the case.

A fifth of a gram was dissolved in sulphuric acid with a known amount of ferrous ammonium sulphate. All precautions were observed to avoid the presence of air, the entire operation being conducted in an atmosphere of carbon dioxide. The water used had been boiled and cooled out of contact with air. Just before the iron sulphate was introduced into the flask containing the mineral, an equal quantity was removed from the stock solution and titrated with permanganate. Thus, the amount of ferrous iron introduced into the flask with the mineral was known. After the mineral had been decomposed by the sulphuric acid, the flask was cooled and the solution titrated, the amount of iron sulphate oxidized by the liberation of oxygen from the mineral being determined in this way. From these data the amount of Mn_2O_3 was calculated and found to be 30.47 per cent.

A second sample was decomposed by hydrochloric acid and the chlorine evolved passed into a solution of potassium iodide. The liberated iodine was then titrated with sodium thiosulphate, the latter being standardized with pure copper. Calculating from the results obtained, the amount of Mn_2O_3 was found to be 27.93 per cent. Though these results vary somewhat, yet, considering the small amount of material used

(1/5 gram) and the many operations necessary, the agreement is as close as could be expected. The average of the two results is 29.20 per cent.

A direct determination of the total manganese, weighed as anhydrous sulphate, gave as the amount of Mn_2O_3 in the mineral, 29.35 per cent, which agrees almost exactly with the average of the two indirect determinations.

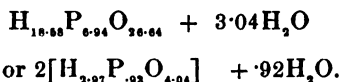
The remaining constituents were determined as follows: A portion of the mineral was dissolved in hydrochloric acid and a known weight of iron added (as ferric chloride). A basic acetate separation was then made, boiling the solution for fifteen minutes, which according to Bunsen will precipitate all the phosphoric acid with the iron and will not precipitate any manganese. The precipitate was dissolved in hydrochloric acid, and reprecipitated by ammonia, after the addition of some ammonium chloride. The two filtrates were united, manganese precipitated by hydrogen sulphide and finally weighed as anhydrous manganese sulphate. Calcium was then thrown out, dissolved and reprecipitated and magnesia found to be absent. The iron-phosphate precipitate was dissolved in hydrochloric acid and divided into two portions. In the one, the iron and phosphoric acid were precipitated by ammonia and weighed. This was then fused up with sodium bisulphate and tested for manganese with silver nitrate and ammonium persulphate. None was present. In the second portion, the iron was reduced by hydrogen sulphide and titrated with permanganate. Phosphoric acid was determined in the usual way and a second value obtained by the difference between the iron and the iron plus phosphoric acid. The alkalis were determined by the Lawrence Smith method. The final solution of chlorides gave a strong spectroscopic test for lithium. The water below 105° was determined directly, using a toluene bath. The total water was determined directly by heating in a glass tube according to Penfield. The water is all given off at a low temperature, that at 105° being given off very readily, and at one time. Further heating at 105° failed to remove any more. The values obtained are as follows:

		Av.	Ratio.	
Fe_2O_3	15.89,	15.89	1.03	} 2.96
Mn_2O_3	29.35, 30.47, 27.93	29.25	1.93	
P_2O_5	47.64, 46.96	47.30	3.47	
H_2O	5.26	5.26	3.04	} .41
CaO	1.48	1.48	.27	
Na_2O .....	.84	.84	.14
Li_2O	tr.	tr.		
Insol.52	.52		

100.54

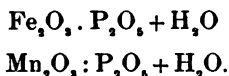
The amount of water given off at 105° is 3.31 per cent. As all of the water is so readily given off, it is most probably present as water of crystallization.

Considering that the calcium and soda require some phosphoric acid, the ratio of $R'''_2O_3 : P_2O_5 : H_2O$ is approximately 3:3:3. Combining the ratio of the calcium and sodium with that of the iron and manganese, and reducing these to their hydrogen equivalent, the ratio becomes



The acid is therefore H_3PO_4 . The formula for the mineral then becomes $R'''_2O_3 \cdot P_2O_5 + H_2O$.

It is not known in just what state of combination the calcium and sodium are. They most probably represent some slight impurity. If the manganic and ferric oxides are isomorphous in the sense that manganous and ferrous oxides are, the ratio of Mn_2O_3 to Fe_2O_3 being nearly 2:1 is of no significance and the formula then should not be written $Fe_2O_3 \cdot 2Mn_2O_3 \cdot 3P_2O_5 + 3H_2O$, but $(Mn''', Fe''')_2O_3 \cdot P_2O_5 + H_2O$, the mineral purpurite being near the manganic end of an isomorphous series having as its two end members:



There are only a few hydrous phosphates of the normal division in which the base is trivalent, such as scorodite and strengite. All of these, however, contain more water than the mineral here described.

While no manganic phosphates were noted in the literature, there are a number of arsenates containing Mn_2O_3 , with none of which, however, can purpurite be classed. Synadelphite, flinkite, arseniopleite, and perhaps hematolite, contain Mn_2O_3 with Al_2O_3 or Fe_2O_3 , while in durangite and arseniosiderite, Mn_2O_3 is reported in small amounts.

The mineral fuses easily and readily gives off water in a closed tube becoming yellowish brown. It is readily soluble to a clear solution in hydrochloric acid, while in nitric acid a black oxide of manganese separates out. The specific gravity determined on the powdered mineral by the Thoulet solution is approximately 3.15.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Studies with the Liquid Hydrogen and Air Calorimeters. I. Specific Heats* ;* by Sir JAMES DEWAR.—“The calorimeter employed in the following researches was similar to that described in my paper on ‘The Scientific Uses of Liquid Air,’† and in an improved form in Madame Curie’s work ‘Recherches sur les Substances Radio-Actives,’ 2d edition, p. 100. A sketch of the apparatus appears in my paper on ‘The Absorption and Thermal Evolution of Gases Occluded in Charcoal at Low Temperatures.’‡

The arrangement employed consists essentially of a large vacuum vessel capable of holding 2 or 3 liters, into which is inserted a smaller vacuum vessel of 25 to 50 c.c. capacity constituting the calorimeter, the latter being sealed on to a long narrow tube which projects from the mouth of the exterior vessel, in which it is lightly held by a loose packing of cotton wool. A little below the upper end a branch tube is taken off which conveys the volatilized gas from the calorimeter to the gas receiver. To the extremity of the projecting tube a small test-tube, to hold the portions of substance experimented on, is attached by a short piece of rather wide rubber tubing which forms naturally a movable joint that can be bent into any position. With care I have found this valve gives as good results as more elaborate means of securing the dropping of the substances into the calorimeter. A small vacuum vessel containing solid carbonic acid, liquid ethylene, liquid air, etc., into which the test-tube is placed, cools the materials to different temperatures below those of the laboratory, or alternatively it may be heated in the vapour of water or other liquids.”

The general constants for liquid gas calorimeters (here omitted) show that “an instrument in which liquid air is used has twice the sensibility of a corresponding one in which liquid ethylene is employed, whereas the substitution of liquid hydrogen for liquid air increases the delicacy of the calorimeter some seven times. It is easy to detect the transference of 1/50 of a gram-calorie in the liquid air instrument, whilst 1/300 of a gram-calorie can be similarly observed in the liquid hydrogen form of the calorimeter.”

A detailed account is given of the method of use of the instrument and also of the various sources of error. Of the experiments described the following results were obtained for carbon in the form of diamond and of graphite, and for ice.

* Extracts from an advanced proof (received from the author) of a paper read June 8, before the Royal Society of London.

† Proc. Roy. Inst., 1894, vol. xiv, p. 398.

‡ Proc. Roy. Soc., 1904, vol. lxxiv, p. 123.

Substance.	18° to -78°.	-78° to -188°.	188° to -252°·5.
Diamond	0·0794	0·0190	0·0043
Graphite	0·1341	0·0599	0·0133
Ice	0·463*	0·285	0·146

"It appears from these values that between the ordinary temperature and the boiling point of hydrogen the specific heat of the diamond has been reduced to 1/19, whereas under similar conditions graphite has diminished to about 1/10. Further it will be observed that at the lowest temperatures the specific heat of graphite is about three times that of the diamond. It is also worthy of being recorded that the values of the specific heats of diamond and graphite taken between the temperatures of liquid air and boiling hydrogen are far smaller than that of any known solid substance, being even lower than that of any gas taken under constant volume."

Another table gives the results obtained, at temperatures extending down to -188°, for the specific heats of various substance including German-silver, brass, tellurium, sulphur, etc., to solid carbon dioxide, solid ammonia and solid sulphur dioxide. The author concludes with the remark that "an almost endless field of research in the determination of specific heats is now opened, in which the use of liquid air and hydrogen calorimeters are certain to become ordinary laboratory instruments."

2. *On the Thermo-electric Junction as a Means of Determining the Lowest Temperatures*; by Sir JAMES DEWAR.†—"The inconvenience of using the gas thermometer at very low temperatures and the failure of platinum and other metal-resistance thermometers within 30° or 40° of the absolute zero, led me some years ago to consider the experimental behavior of the thermo-electric junction at the lowest temperatures. My special object at the time the experiments were made was to have a further confirmation of the melting point of hydrogen, and also of the lowest temperature reached on exhausting solid hydrogen, other than that I had found by means of the hydrogen gas thermometer.‡ The results have remained unpublished, because my intention has always been to extend them to other thermo-electric combinations. Not having been able to accomplish this project, they are now abstracted as affording useful information in this field of investigation, and as furnishing a general confirmation of my previous investigations.

A German-silver platinum couple was selected as likely to give the most uniform results at low temperatures, although subsequent experiments have led to the conclusion that it would have been better to have replaced the platinum by gold. As regards resistance thermometers, I have shown that gold is more reliable

* This from -18° to -78°.

† Extracts from an advance proof (received from the author) of a paper read June 8 before the Royal Society of London.

‡ The Boiling Point of Liquid Hydrogen, determined by Hydrogen and Helium Gas Thermometers, Proc. Roy. Soc., vol. lxxviii, 1901.

than platinum at temperatures near the boiling point of hydrogen.* The difficulties of the investigation were considerable: it had to be carried out at the time in the neighborhood of the machinery producing the liquefied gases required in the investigation, namely, oxygen, nitrogen, and hydrogen, so that the zero of the delicate galvanometer employed did not remain quite constant. To remedy this I inserted a rocking make-and-break in order to get the readings of each observation at both ends of the scale. In the process of removing one difficulty another presented itself, through the development of small but appreciable thermo-electric currents in the rocker. Precautions had to be taken against these and at all other metal junctions against similar small thermo-electric currents, and it was even found necessary to have a correction on account of the resistance box, inserted in the circuit to bring large readings within the limits of the scale. The galvanometer and resistance box were inserted in the German-silver branch of the couple, the points of junction of the copper leads with the German silver ends of the couple being insulated and placed close together within a vacuum test-tube packed with cotton wool to ensure equality of temperature.

Preliminary experiments showed that the junctions altered after having been subjected to the temperature of liquid hydrogen. However, on re-soldering the junctions with hard silver solder instead of soft solder, the thermo-couple accurately repeated observations at the temperature of liquid oxygen, after having passed through a liquid hydrogen bath. From this it appears that all such couples before calibration ought to be cooled suddenly in liquid air and then rapidly heated to the ordinary temperature, a similar operation being repeated with liquid hydrogen. If the couples return to their original state after such abrupt changes of temperature, then they are in a fit state for calibration.

Three series of observations were made to determine whether the resistance of the junctions varied to a noticeable extent with the temperature, namely, at the freezing point of water, at the boiling point of oxygen, and at the boiling point of hydrogen. Six very concurrent observations with varying resistances in the resistance box were made between 0°C. and 15°C. These were reduced by the method of least squares, and gave for the resistance of the circuit 3.500 ohms. Five similar results between the melting point of nitrogen and the boiling point of oxygen gave, by least squares, 3.293 ohms. Only two observations were taken in liquid hydrogen, which are therefore not entitled to the same weight as those already given, but the resistance appeared again about 3.3 ohms. As the variation of the resistance of the circuit was so slight, an attempt was made to reduce the results on the assumption of constancy, but this was not satisfactory. However, on treating the variation of the resistance of the circuit as linear with the temperature, the data came into better agreement.

* Bakerian Lecture, "The Nadir of Temperature and Allied Problems," Proc. Roy. Soc., vol. lxviii, 1901.

The following table contains the details of the observations made with the silver soldered German-silver platinum couple, the recorded readings of the galvanometer being the means of several observed readings, corrected when necessary for resistance introduced into the circuit :—

No. of expt.	Substances used for difference of temperature.	Corresponding absolute temperatures.	Mean absolute temperature.	Mean galvanometer reading.	dE/dt .
1	Water of 15° and ice	280°, 273°	280½°	463·2	30·88
2	Boiling carbonic acid and ethylene.....	195, 170	182½	693·5	27·74
3	Boiling ethylene at 10 ^{mm} and oxygen..	123½, 90½	107	724·0	21·94
4	Boiling oxygen and nitrogen	90½, 77½	84	279·0	21·46
5	Boiling nitrogen and melting nitrogen..	77½, 62½	70	320·7	21·38
6	Boiling hydrogen and melting nitrogen..	62½, 20½	41½	623·5	14·84
7	Boiling hydrogen and melting hydrogen..	20½, ?	?	51·0	?
8	Boiling hydrogen—solid hydrogen about 20 ^{mm}	20½, ?	?	64·0	?

where dE/dt is the quotient of the mean galvanometer reading by the difference of the temperatures in the third column.

On plotting the first six of these results the 1st, 2d, and 6th and means of the other three, viz., $dE/dt = 21·59$ at $t = 87^\circ$, lie nearly on a continuous curve. The continuity of the curve, without any approach to abrupt change of form, even in the region of liquid hydrogen, shows that a silver-soldered German-silver platinum couple is an efficient instrument for the determination of the lowest temperatures hitherto reached."

A detailed discussion of the four sets of observations, Nos. 3, 4, 5, 6, follows, with the results given below ; those from Nos. 5 and 6 are probably the most accurate.

"The general results with the German-silver platinum junction may be summarized in the following table, the typical equation being $dE/dt = m + nT$.

Source of constants.	m	n	Melting point of hydrogen.	Solid hydrogen exhausted.
(3) and (6)	12·52	0·108	16°·4	15°·27
(4) and (6)	11·49	0·158	15°·9	14°·7
(5) and (6)	9·931	0·231	15°·0	13°·5
Graphically	10·2	0·167	15°·5	14°·15
Mean	-----	-----	15°·7	14°·4

It is added that in the paper on liquid hydrogen, already referred to, the temperatures obtained by the hydrogen gas thermometer for the boiling point of hydrogen and the solid under exhaustion were $19^{\circ}63$ and $14^{\circ}34$ respectively. Finally it is concluded that, "at as low a temperature as 6° absolute, the sensibility of this couple is still half what it was at $20\frac{1}{2}^{\circ}$ absolute, and therefore that, unless some absolute breakdown in the law connecting electromotive force and temperature below 14° takes place, it must continue to be an excellent thermometer, and will record temperature with considerable accuracy down to the boiling point of helium, which is about 5° or 6° degrees absolute."

II. GEOLOGY.

1. *Geology of the Vicinity of Little Falls, Herkimer County*; by H. P. CUSHING. Bull. 77, New York State Mus., 1905, pp. 95, pls. 1-15, and topographic and geologic maps.—Mr. Cushing here gives an account of the geology of one of the most interesting regions in New York. In this presentation he does not limit himself to the area of his map, but notes as well the general geology of the Adirondack region, thus setting forth in a philosophical manner the historical events which have taken place in northeastern New York.

The author states that the Adirondacks formed a low-lying land when the Potsdam sea encroached upon it. "It is possible that a small area may have persisted above sea level throughout [to the close of Utica time], though it is not likely, and in any case it was very small." The southern part of the Adirondack mass was the last to pass beneath the sea. The Potsdam is thickest on the northeast border, thinning out both westward and southward; it is not known on the south side about Little Falls. Upon the Potsdam along the eastern side was laid the Beekmantown limestone, but, according to the reviewer, it is questionable whether the so-called Beekmantown of the southern exposure is of the same age. These southern dolomites are 450 feet thick at Little Falls, but diminish to "nearly or quite zero at the northern limit of the sheet." Upon this formation in both areas follow the limestones of the Mohawkian series and then the Utica shales. At the top of the Utica "the present Adirondack region was either wholly submerged or else so nearly so that only a few small islands were left protruding above the water." This is not the generally accepted view and the occurrence of Potsdam within the Adirondack mass will have to be explained as depressed fault-blocks.

"Following the deposition of the Utica formation came a movement of disturbance and uplift of the region on the northeast and east. This apparently raised the present Champlain valley and northern Adirondack region above sea level, while the southern portion was not affected and remained submerged. . . .

"Quite possibly the first faulting of the region took place at the close of the Lower Silurian coincidently with the Taconic

disturbance. . . . The Little Falls fault has a throw of nearly or quite 800 feet at Little Falls."

One of the most interesting problems suggested by this bulletin is—What is the relation of the so-called Beekmantown formation of this Little Falls region to the true Beekmantown of the Champlain valley? The author shows how these dolomites overlap and disappear northward over the Adirondack mass. "Nor does the basal bed at Little Falls appear to represent the real base of the formation, deep well records to the west seeming to indicate an increased thickness in that direction." The sequence of the Upper Cambrian and the succeeding dolomites of the Great Interior Sea apparently denote continuous deposition and show that the dolomites along the south side of the Adirondacks are those of a shallow sea, with a sparing fauna. Their age is probably closely connected with the Cambrian and is doubtless older than the Beekmantown of the Lake Champlain area. The faunas of the two areas are widely different, that of the Lake Champlain district being a normal marine one abounding in large cephalopods and gastropods, hardly any of which are found in the Mohawk valley. Again, the sequence varies greatly in the two areas, as in the Lake Champlain region the Beekmantown is followed by the Chazy, while in the Mohawk valley the Lowville reposes on the so-called Beekmantown dolomites. On the northeast side of the Adirondacks the Paleozoic section is at least 3000 feet thicker than in the Mohawk valley.

C. S.

2. *Geology of the Watkins and Elmira Quadrangles, accompanied by a geologic map*; by JOHN M. CLARKE and D. DANA LUTHER. Bull. 81, New York State Mus., 1905, pp. 1-29, with a map and a section.—This Bulletin describes in detail the Upper Devonian strata of these quadrangles, with considerable notation of the occurrence of the faunules of the following horizons :

		Feet.
Neodevonian	Chatauquan	Chemung sandstone and shale 800
		Prattsburg shale..... 250
		High Point sandstone..... 85
		West Hill flags and shale... 315
		Grimes sandstone..... 75
	Senecan	Hatch shale and flags..... 440
		Rhinestreet black shale..... 1
		Parrish limestone, in the
		Cashaqua shale..... 207
		West River shale..... 35
		Genundewa limestone..... 1
		Genesee shale..... 6 +

Much detail is presented in regard to the distribution of the characteristic Naples or black shale fauna and its interlocking but rarely commingling with the eastern or Ithaca fauna. The latter is a direct outgrowth of the Hamilton, as may be seen from

Bulletin 82, reviewed below. The eastern or Ithaca fauna appears for the first time, but sparingly, in the lower portion of the Cashaqua shale, as far west as the region about Watkins Glen, and there are several alternations of this fauna with the Naples in the higher Hatch shale. The Iowa Lime creek fauna of 32 species has its only occurrence near the middle of the High Point sandstone, while *Spirifer disjunctus*, apparently a migrant also from the west or southwest, is seen for the first time in the Genesee valley, in the lower portion of the Prattsburg shale. "The horizon of *Spirifer disjunctus* follows close on the change from the Naples fauna in western New York at a high altitude above the base of the Portage formation. In central New York there is no such change, but the gradation from the Ithaca fauna out of the Hamilton fauna upward into the association which carries species elsewhere concurrent with *Sp. disjunctus* is very easy, and it is extremely difficult to draw a division plane anywhere except on the basis of refined distinctions into successive faunules. *Spirifer disjunctus* in this eastern region did not appear till this period of 'Chemung' deposition was well nigh over." c. s.

3. *Geologic Map of the Tully Quadrangle*; by JOHN M. CLARKE and D. DANA LUTHER. Bull. 82, New York State Mus., 1905, pp. 35-70, with map.—This Bulletin describes the following formations:—

				Feet.		
Neodevonian	Senecan	{	Ithaca	Ithaca flags and sandstones	450	
			Portage	Sherburne flags	210	
			Genesee	Genesee shale	75	
			Tully	Tully limestone	23	
Mesodevonian	{	{	Hamilton	Moscow shale	180	
			Marcellus	Ludlowville shale	350	
				Skaneateles shale	335	
				Cardiff shale	175	
				Marcellus shale	100	
Paleodevonian	{	{	Ulsterian	Onondaga	Onondaga limestone	65
			Oriskanian	Oriskany	Oriskany quartzite	6
			Helderbergian	Helderberg	New Scotland	
					limestone and	
					Coeymans limestone	40
Silurian	Cayugan	{	Manlius	Manlius limestone	74	
				Rondout dolomite	40	
				Cobleskill dolomite	6	
				Bertie dolomite	15	
			Salina	Camillus shale	40	

The evidence regarding the presence of the New Scotland in this area is not convincing. As the present writer did not find this formation to the east, about Litchfield, it appears to him more probable that the New Scotland does not occur in the Tully quadrangle.

Dr. Clark adds a chapter on the "Ithaca fauna of Central New York," and lists 199 species collected by Mr. Luther from 80 stations. Of these forms, not less than 106 occur beneath the top of the Tully, abundantly confirming the statement of the author that "the fauna in point of number is prevailingly affiliated to that of the Hamilton."

The leading Hamilton species commonly found at these stations are the following: *Phacops rana*, *Pleurotomaria sulcomarginata*, *Actinopteria boydi*, *Glyptodesma erectum*, *Modiomorpha concentrica*, *M. mytiloides*, *Grammysia bisulcata*, *Cimitaria recurva*, *Microdon bellistriatus*, *Nuculites oblongatus*, *Nucula bellistriata*, *Palæoneilo emarginata*, *Paracyclas lirata*, *Rhipidomella vanuxemi*, *Spirifer mucronatus*, *Cyrtina hamiltonensis*, *Camarotoechia congregata* and *Tropidoleptus carinatus*. c. s.

4. *Contribution to the Paleontology of the Martinez group*; by CHARLES E. WEAVER. Univ. California Pub., Bull. Dept. Geol., pp. 101-123, pls. 12, 13, date of printing not given.—This Eocene fauna consists of 67 species. Of these 18 are new and with 3 others are described and illustrated.

"The Martinez represents a distinct division of time in the geological history of California. It contains a fauna distinct from both the Chico and the Tejon. On the average it is composed of about two thousand feet of thick-bedded sandstones, together with some shales, thin-bedded sandstones and conglomerates. . . . Its position in the geological scale seems to correspond most closely to a portion or all of the lower quarter of the Eocene."

"There was probably no direct faunal connection between India and the Western Coast of North America in Martinez times. . . . The evidence seems also to point to the fact that during this period the Martinez seas were isolated from the regions of the southeastern United States." c. s.

5. *Faune cambrienne du Haut-Alemtejo (Portugal)*; par J. F. NERY DELGADO. Comm. Serv. Geol. du Portugal, v, 1904, pp. 307-374, pls. 1-6.—This work describes a very interesting Lower Cambrian fauna. It is especially noteworthy because of an abundance of bivalve shells of which 9 species are described, whereas in North America the *Olenellus* fauna is known to have but 2 species and but one of these is common.

The author regards this fauna as probably Lower Cambrian; from a survey of the genera adopted, however, his readers would be perplexed to know to what age these beds should be referred, were it not for the good photographic plates illustrating the species. *Paradoxides choffati* is clearly an *Olenellus*. The several species (9) of *Hicksia* are very suggestive of Lower Cambrian *Solenopleura* and especially of a form found at York, Penn. Of *Microdiscus*, the author describes 5, but *M. caudatus*, *M. subcaudatus*, and *M. wenceslasi* must be placed under a new genus, because they have dorsal eyes and a caudal spine. As *M. souzai* and *M. woodwardi* have eyes, they, too, should be referred to

another genus. It may be best to erect a new genus with *M. woodwardi* as the genoholotype, and a new subgenus with *M. caudatus* as the type species.

The Pelecypoda, as far as their generic reference is concerned, are very inadequately treated. One is referred to *Posidonomya*?, 2 to *Modiolopsis*, 1 to *Syneke*?, 3 to *Davidia*, and 1 to *Ctenodonta*. While these names may indicate the types of pelecypods represented, yet it is safe to state that a careful study will show that all belong to other, probably new genera. The species are small and thin-shelled. In a conversation with Professor Verrill he concluded that all these Lower Cambrian bivalves were probably free-swimming forms.

The brachiopods are also very unsatisfactorily referred generically, and the illustrations are inadequate for more accurate determination.

This fauna of Portugal is certainly of Lower Cambrian age, and while it has relationship with that of York, Penn., yet in its trilobites and especially in its pelecypods it has a faunal facies entirely distinct from any American Lower Cambrian fauna.

C. S.

6. *Paraphorhynchus*, a new genus of *Kinderhook Brachiopoda*; by STUART WELLER. Trans. Acad. Sci. St. Louis, xv, 1905, pp. 259-264, pl. 1.—This rhynchonelloid form has the interior generic characters of *Camarotoechia*, with the exterior of *Pugnax*, to which is added a finely striated surface of the shell. The genoholotype is *Paraphorhynchus elongatum*, sp. nov. Other species are *P. transversum*, sp. nov., *Rhynchonella striatocostata* Meek and Worthen, *R. medialis* Simpson, and *R. striata* Simpson.

C. S.

7. *Sympterura Minveri*, n. g. et sp.: a Devonian Ophiurid from Cornwall; by F. A. BATHER. Geol. Mag., II, 1905, pp. 161-169, pl. 6.—This important paper describes in detail the skeleton of this brittle-star. The description is followed by a learned interpretation of the parts of the organism and their relation to other ophiurid structures.

C. S.

8. *The ancestral origin of the North American Unionidæ, or fresh-water Mussels*; by CHARLES A. WHITE. Smithsonian Misc. Coll. (Quarterly Issue), June, 1905, pp. 75-88, pls. 26-31.—After a long silence in Paleontology, Dr. White returns to a group of shells on which he has often worked.

The oldest American Unionidæ occur in the Triassic. They "are all of simple form, and none of them exhibits distinctive prototypal relationship to the living Mississippi River fauna." Of Jurassic species, but seven are known and none of these appears to be directly related to the living shells. Toward the close of the Cretaceous, "the family received an extraordinary development" and increased its diversity. In the Laramie strata are found the greatest number of species of *Unio* having prototypal features connecting them with existing species in so marked a manner "that Professor Whitfield has given names to

the fossil forms [three] which are only modifications of the names of the living forms which they so closely resemble." In the Tertiary all connecting forms are absent, but the author explains that the Cenozoic species thus far found are plain types such as are now obtained only in still waters or lakes. "The more diverse and ornamental forms of living Uniones occupy fluviatile, or other running or moving waters. None of the deposits containing the Tertiary Uniones referred to gives any inherent evidence of having been formed in fluviatile or estuarine waters."

"Fresh-water gill-bearing faunas have as certainly descended genetically through successive geological ages to the present time as have marine faunas. . . . There has never been any intermission of such continuity because the fresh-water supply has never failed, and because, as a rule, rivers have been among the most persistent of the earth's surface features." c. s.

9. *The Thalattosauria, a group of marine reptiles from the Triassic of California*; by JOHN C. MERRIAM. Mem. California Acad. Sci., V, 1905, pp. 1-52, pls. 1-8.—During the past three years the Geological Department of the University of California has been collecting the remains of the marine reptiles from the Upper Triassic of Shasta county. From the fact that both are black, the material is very difficult to clear from the matrix, the latter being a shaly limestone.

This memoir describes in detail the skeletal structure of the Thalattosauriæ, comprising the genera *Thalattosaurus* (*T. alexandrae*, *T. shastensis* sp. nov., *T. perrini* sp. nov.) and *Nectosaurus* gen. nov. (*N. huius* sp. nov.). The pen and ink illustrations are good.

"The Thalattosaurs represent an early adaptation to marine conditions of that division of the Reptilia which has persisted in measurably primitive form in the Rhynchocephalia. During the early history of that group it gave rise to a numerous company of forms taking quite divergent paths in their evolution. Of the older orders only the Proganosauria were aquatic. They appear, however, to have been limited to fresh water. The Thalattosaurs are evidently the marine representatives of this great rhynchocephalian or diaptosaurian group." c. s.

10. *The Geology of Littleton, New Hampshire*; by C. H. HITCHCOCK. Pp. 38, 2 plates and map. Reprinted from History of Littleton, 1905.—This paper brings together all that is known in regard to the geology about Littleton, including the recently published article by Hitchcock (Bulletin Geol. Soc. America). The strata present are referred to the Quaternary, Helderberg, Silurian, Lower Silurian or Cambrian, and eruptives. In an appendix, Mr. Avery E. Lambert describes a new trilobite, *Dalmanites lunatus*, with notes on other fossils from the Littleton area. c. s.

11. *Vorschule der Geologie*; von JOHANNES WALTHER. Pp. 144, and 98 original text figures. Jena, 1905.—This very interestingly written, simply stated, and well printed little book on elementary geology is intended for beginners in geology. They

AM. JOUR. SCI.—FOURTH SERIES, VOL. XX, No. 116.—AUGUST, 1905.

are led to observe nature for themselves and are shown how to determine the stratigraphic sequence in the profiles leading up to map making. Comparative stratigraphy and historical geology are not here considered.

There are 18 chapters, as follows: 1. Introduction; 2. Geological exposures; 3. Weathering (physical, chemical, and organic); 4. Results of weathering; 5. Kinds of rocks; 6. Rock-clefts or joints; 7. Subterranean waters and springs; 8. Infiltration of joints and caves; 9. Flowing waters; 10. Standing waters; 11. Sea-shore; 12. Mountains and hills; 13. Deformation and earthquakes; 14. Plutonic appearances; 15. Volcanic activity; 16. Stratigraphic sequence; 17. Maps; 18. Chronological sequence.

The book is distinguished for two things: The "Aufgaben" and the many clear and well-drawn diagrams of geological structures. At the end of each chapter, under "Aufgaben," the student is directed how and where to look for the things described. There are 110 of these lessons. C. S.

12. *Die Moore der Schweiz mit Berücksichtigung der gesamten Moorfrage*; von Dr. J. FRÜH und Dr. C. SCHRÖTER. Herausgegeben von der geologischen Kommission der Schweiz-Naturforschenden Gesellschaft. Preisschrift der Stiftung Schnyder von Wartensee. Pp. 751, 5 plates, figures in text. Bern, 1904.—This voluminous quarto report comprises a most elaborate treatment of swamps and peat-bogs, particularly in regard to those of Switzerland. Dr. Fröh, professor of geography, and Dr. Schröter, professor of botany, at the Polytechnikum at Zurich, have combined in a most thorough manner the knowledge concerning these deposits from the point of view of geography, climatology, and botany. The first part of the work deals with vegetal deposits now making in northwestern and central Europe and in a general way with those of other districts, with reference to the classification of the deposits and an analysis of all the conditions which affect the growth of the plants and the accumulation of vegetal deposits. The second part of the work is devoted to a detailed description of local deposits within the confines of Switzerland. Throughout this work the botanist and the geographer have labored together to present precisely and technically the varied conditions which are displayed in the various plant colonies encountered within their field of study. Over 6,000 microscopic preparations were examined in the study of the stratigraphy of peat-beds. Helpful schematic tables arranged in the form of geological cross-sections of the types of swamp-accumulations present a summary of the chapters of description, in which climate, altitude, position in relation to sunshine, slope, drainage, and accidental factors, are equally faithfully portrayed with encyclopedic fulness. A useful discussion of the world distribution of vegetal accumulations of the present day is accompanied by a mercator's chart showing the grouping of the broader divisions of vegetal deposits. There is also a chapter on the flora of the interglacial deposits. The authors, notably Fröh, do not find that bacteria are effective producers of the change from

ordinary cellulose to the peaty state of vegetable matter. As a contribution to the æcology of plants the work is of exceptional interest. To the student of Pleistocene and Post-glacial deposits it seems clear that a like investigation of the vegetal deposits of America, for which there is abundant material, would prove equally valuable. There is an appended bibliography of 280 or more papers, and a topographic map of Switzerland on the scale of 1 : 530,000 showing by colors the distribution of swamps.

J. B. W.

13. *A Study of Recent Earthquakes*; by CHARLES DAVISON, Sc.D., F.G.S. Pp. xii + 355, with 80 illustrations. London, 1905 (Contemporary Science Series. The Walter Scott Publishing Co.).—The scope and object of this work are well stated in the opening paragraph of the preface, here quoted :

"The present volume differs from a text-book of seismology in giving brief, though detailed, accounts of individual earthquakes rather than a discussion of the phenomena and distribution of earthquakes in general. At the close of his *Les Tremblements de Terre*, Professor Fouqué has devoted a few chapters to some of the principal earthquakes between 1854 and 1887; and there are also the well known chapters in Lyell's *Principles of Geology*, dealing with earthquakes of a still earlier date. With these exceptions there is no other work covering the same ground; and he who wishes to study any particular earthquake can only do so by reading long reports or series of papers written perhaps in several different languages. The object of this volume is to save him this trouble, and to present to him the facts that seem most worthy of his attention."

The eight earthquakes selected are those which have been most thoroughly studied, "or which are of special interest owing to the unusual character of their phenomena, or the light cast by them on the nature and origin of earthquakes in general."

This volume is a welcome addition to recent earthquake literature, and forms what may be regarded as a valuable supplementary volume to the recent work of Dutton's treating of earthquakes in general.

J. B.

14. *An Introduction to the Geology of Cape Colony*; by A. W. ROGERS, Director of the Geological Survey of Cape Colony. With a chapter on the fossil reptiles of the Karroo Formation by Prof. R. BROOM, M.D., BSc., of Victoria College, Stellenbosch. 463 pp., 21 plates, 22 text figures and a colored geological map. London, 1905. (Longmans, Green & Co.).—This well written and clearly printed book makes a very desirable addition to geological literature, bringing into one compact volume the geology of Cape Colony and enabling the specialist in other geological fields to gain, with a minimum of effort, a comprehensive idea of this distant part of the earth.

The Cape System is the oldest within which organic remains have been found, the middle member consisting of shales and thin sandstones 2500 feet thick containing fossils identical with or closely related to species which are found in Devonian rocks

of America and Europe. Beneath the Cape System are found a great thickness of closely folded and metamorphosed sedimentary formations largely injected with granite and embracing as many as four unconformable subdivisions.

The base of the Cape System consists of the topographically prominent Table Mountain sandstone, with a maximum thickness of 5000 feet, remarkably constant in character over the whole area of its present occurrence, probably over 90,000 square miles, pointing to its deposition over a wide shallow platform with unknown limits fronting a land which probably lay to the northward. An interesting feature is the occurrence of a thick shale-band with pebbles up to five inches in diameter occasionally flattened and striated. The pebbles are scattered irregularly through the shale and mudstone without any tendency to form beds of conglomerate. Considering all the evidence, it is concluded that the pebbles were distributed by floating ice somewhere early in Neopaleozoic times.

Following the Cape System, conformably in the south but unconformably in the northern portion of the Colony, is the Karroo System, with a maximum thickness of not less than 14,000 feet; it is rich in the remains of Permo-Carboniferous and Triassic reptiles. Its base, the Dwyka Conglomerate, a thousand feet in thickness, appears to consist in the south of iceberg deposits and in the north of true boulder clay resting unconformably upon striated and moutonnéed surfaces with indications of ice movement from the north toward the south. Several plates from photographs illustrative of these highly interesting occurrences are given.*

Sometime after the middle of the Karroo a period of folding set in, building the mountain structures of Cape Colony facing outwards toward the oceans. This was followed by a period of great basic intrusions and of volcanism closing the Triassic. Since that time the history of Cape Colony has been preëminently one of successive uplifts and erosion; an erosion history interrupted in early Cretaceous times by a partial subsidence and probably an increased aridity of climate, and checked occasionally in later times by an approach of the river valleys to base level.

It is to be noted that on the southeast the even coast line cuts across the folded structures for a distance of four hundred miles, and there are indications, as in a downfaulted remnant of the Cretaceous, that post-Cretaceous faulting has played an important part in this truncation of older structures and the present termination, at this place, of the continental platform. J. B.

15. *Ice Erosion Theory a Fallacy*; by H. L. FAIRCHILD. Bull. Geol. Soc. Amer., vol. xvi, pp. 13-74, pls. 12-23. Published Feb., 1905. Read Jan. 1st and Dec. 30th, 1904.—In this article the author defines glacial erosion as the power of making vast and deep excavations in the solid or live rock, resulting in

* See also the article on this subject by E. T. Mellor in this number, pp. 107-118.

the excavation of fiords and large lake basins, a power which is questioned by many geologists and accepted by others equally, if not more, numerous; the capacity of removing loose material and of plucking away frost-loosened blocks, especially where facilitated by vertical jointing, being, on the other hand, universally conceded.

The arguments for deep erosion are discussed in detail and are considered to be inconclusive. Following this, concrete illustrations are given from several glaciated mountain ranges, showing a scouring and polishing action in valleys originating from preglacial erosion rather than a topographic transformation of the preglacial surface.

Among the important consequences from such conclusions, Fairchild considers that fiords and hanging valleys may and ordinarily do occur as the result of preglacial erosion, masked, however, by the glacial occupancy and signifying therefore certain preglacial changes in the altitude of the land. It is conceded, however, that glacial action emphasizes and makes more conspicuous hanging valleys of preglacial origin.

Following the above is a discussion of the evidence from the state of New York, with the conclusion that continental as well as Alpine glaciation is ineffective as a powerful erosive agent.

In many ways the quantitative value of ice erosion is an important problem and the writer has certainly presented ably his views upon the subject, but they would probably have met with a readier acceptance among those holding different opinions if prefaced with a less assertive and combative title. Many details of the argument, such as the significance of cross striae as indicative of weak erosive power, are still open to discussion in a manner similar to that on the subject of hanging valleys; but coming down to the essential conclusions of the problem, Professor Fairchild and many of his opponents upon this question are probably nearer together than would at first appear, the problem turning on the quantitative value of ice erosion: the one side holding that it is rapid and important, the other that it is slow and very subordinate to the aggregate effects of the previous fluvial and subaërial sculpture.

J. B.

16. *Hanging Valleys*; by I. C. RUSSELL. Bull. Geol. Soc. Amer., vol. xvi, pp. 75-90. Read Dec. 30th, 1904. Published Feb., 1905.—A number of prominent physiographers have considered hanging valleys to result as a rule from the unequal erosion of valleys by glaciers of unequal size and to represent therefore the differential erosive power of the main and tributary glaciers, the total erosive power being necessarily still greater.

Dismissing the idea of glacial action as being the sole or necessary cause, a hanging valley may be defined, as stated by Chamberlin and Salisbury, as "when the lower end of the tributary valley is distinctly above the level of its main." On this basis Russell divides hanging valleys into four species, namely, stream-formed, ocean-formed, diastrophic, and glacier-formed. Even

among the glacier-formed "there appear to be at least six sets of conditions or processes each of which may produce glaciated hanging valleys without necessitating a conspicuously great measure of differential ice erosion." Illustrations confirmatory of these conclusions are cited from Stein mountain in south-eastern Oregon and from the Sierras.

The discussions of this paper may be considered as an amplification of one phase of the general problem presented in Fairchild's paper, and tending likewise to diminish the conception of the total magnitude of ice erosion. J. B.

17. *Glaciation of the Green Mountains*; by C. H. HITCHCOCK, LL.D., pp. 21. Montpelier, Vt. (Argus and Patriot Press, 1904).—After a review of the literature and an examination of the data in regard to all the higher summits of New England and New York, Dr. Hitchcock concludes that all, including Mt. Katahdin, Mt. Washington and Mt. Marcy, were completely buried beneath the continental ice and that any nunataks must be sought for among the Catskills or some other highland comparatively near the ice-border just as they are in Greenland to-day. J. B.

18. *Ice or Water*; by SIR HENRY H. HOWORTH. In three volumes. London, 1905 (Longmans, Green & Co.).—This voluminous work, each volume consisting of some five hundred pages, is by the author of a previous work of the same character entitled "The Glacial Nightmare and the Flood." He calls the present volumes "Another appeal to induction from the scholastic methods of modern geology," and reiterates and amplifies the views current in regard to the origin of the "drift or diluvium" previous to 1840.

For geologists there is no need of a review of this work as the titles of this and the previous one are sufficiently explanatory, but as the former has met with some little acceptance among those interested in geology but not specialists in the science, as is witnessed in a recent work by the Rev. N. Hutchinson, and as this is doubtless intended for the same class of readers, it may be well to say that the conclusions drawn in these volumes are essentially those held previous to 1840, thoroughly threshed out during the next twenty years and as thoroughly abandoned by all active geologists for the past thirty. A considerable part of the argument turns upon the idea that since the *causes* of the ice age are but poorly understood and there is as yet no unanimity of opinion upon that subject, therefore it is bad logic to believe in the existence of an age of ice at all.

The author has, however, read up glacial literature with considerable thoroughness, and he destroys to his satisfaction every theory of the glacialists including those which are founded upon the best accepted facts as well as those proposed upon insufficient knowledge and which have been already left by the wayside by all prominent glacialists themselves. In reading these volumes one is reminded of a criticism of Brögger dealing with a similar reversion to an earlier period of thought "Der menschliche Geist

ist wunderbar konservativ: denn Ansichten, die man schon längst als todt und begraben ansehen müsste, stehen immerfort wieder als Gespenster aus der Vergangenheit auf." J. B.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The United States National Museum*; by RICHARD RATHBUN. Report of the U. S. National Museum for 1903, pp. 177-309, with 29 plates. Washington, 1905.—This is a very readable and well illustrated account of the Government Museum buildings in Washington; the first of these is the picturesque Smithsonian building finally completed in 1855 and restored in 1865-1867 after the partial destruction by fire in January, 1865. This was followed by the National Museum, completed in 1881 under Secretary Baird. The plans for the new Museum building, the foundations of which have been recently begun, are also presented.

2. *Forestry: Tenth Annual Report of the Chief Fire Warden of Minnesota*, for the year 1904; by C. C. ANDREWS. 135 pp., with 17 plates.—The annual appropriation by the State of Minnesota in behalf of the preservation of its forests amounts to the very small sum of \$5,000. The present report shows how much can be accomplished with even this amount, and it cannot be believed that the strong plea of the Chief Fire Warden for adequate support and an enlightened policy can be disregarded; certainly the matter is one in which the State has a vital interest.

3. *Les Prix Nobel en 1902*. Stockholm, 1905.—The Swedish Academy of Sciences has recently distributed an interesting volume giving an account of the distribution of the Nobel prizes in 1902, with plates showing the medals and diplomas, also the portraits of the recipients accompanied by brief biographies. The prizes were awarded as follows, viz.: in physics, to H. A. Lorentz and Pieter Zeeman; in chemistry, Emil Fischer; in medicine, Ronald Ross; in literature, Theodor Mommsen. The volume also contains the Nobel lectures by Professors Lorentz, Zeeman, Fischer, Ross and Ducommun.

4. *Negritos of Zambales*; by WILLIAM ALLEN REED. 90 pp., 62 plates. Manila, 1904 (Ethnological Survey Publications, vol. II, Part 1).—Of the various publications which appear from time to time from Manila, not the least important are those devoted to ethnological subjects. The present paper, which forms Part I of vol. II, is devoted to an account of the interesting race of pygmy blacks, the Negritos of Zambales Province; it presents the subject very fully, with a large number of plates, reproduced from photographs.

5. *A Magnetic Survey of Japan reduced to the Epoch 1895-0 and the Sea-level*, carried out by order of the Earthquake Investigation Committee. Reported by A. TANAKADATE. 347 pp., 98 plates, Tokyo, 1904. The Journal of the College of Science, Imperial University of Tokyo, Japan, vol. xiv.—This large volume presents the results of the Magnetic Survey of Japan,

carried on, under the auspices of the Earthquake Investigation Committee, during the four summers from 1893 to 1896. The Appendix gives a complete list of the observations, reduced to 1895.0 and sea-level. A large number of plates and eleven beautifully executed maps accompany the text. Many of the maps are double, a thin rice-paper chart covering a second one on thick paper; in this way a double series of data are presented.

6. *Beiträge zur chemischen Physiologie*, herausgegeben von F. HOFMEISTER. Band VI. 1905. Braunschweig (F. Vieweg und Sohn).—The present volume, like its predecessors, contributes a large number of new data to the literature of physiological chemistry. Only a few of the 41 papers can be selected for special mention in this place. Many of them deal with the chemistry of metabolism. Thus von Bergmann and Langstein have investigated the "residual nitrogen" of the blood; Knop, the metabolism of aromatic fatty acids; Eppinger, the physiological formation of allantoin and urea; Blumenthal, the assimilation limits for common sugars after intravenous introduction; and Steinitz and Weigert, the composition of the body after improper nutrition. Dr. von Fürth has published the details of an extensive study of the oxidative decomposition of proteids. Friedmann's research on the chemical structure of adrenalin, Pollak's paper on the diversity of trypsins, and Embden's various papers on carbohydrate metabolism indicate the scope of the journal. Students of haemolysis and related topics will be interested in the papers by Pascucci upon the chemistry of the stroma of the red blood corpuscles, and one by Hausmann on the behavior of saponin in the presence of cholesterol. L. B. M.

7. *Du Laboratoire à l'Usine*; par LOUIS HOULLEVIGUE, Professeur à l'Université de Caen, 299 pp., 12mo. Paris, 1904 (Armand Colin).—This useful little book discusses in elementary form a wide range of well-selected practical topics: the part played by machines; the gas meter; the transformation and distribution of energy; the industrial Alps; electro-chemistry; lighting by incandescence; the production and use of extreme cold; molecules, ions and corpuscles. The method of presentation is adapted to the requirements of the ordinary public interested in the applications of science.

8. *Traité Complet de la Fabrication des Bières*; par MM. G. MOREAU and LUCIEN LÉVY. 674 pp., 5 plates, 173 figures in the text. Paris, 1905 (Libr. Polytechnique, Ch. Béranger Éditeur, successeur de Baudry et Cie.).—This volume, like others which have preceded it from the same publishers and belonging to this series, is a very complete and exhaustive discussion of the subject of which it treats. This is somewhat out of the range of this Journal, but attention may be called to the discussion of the botanical side of the various forms of hops and barley, also of the yeast, and of the part played by bacteria; these have more than a technical interest. The illustrations are numerous and good and the whole presentation of the technical part of the subject is very thorough.

THE
AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XX. — *Development of Fenestella*; by EDGAR ROSCOE CUMINGS, Ph.D. (With Plates V, VI, and VII.)

Introduction.

DURING the past two years, the writer's studies of the development of Paleozoic Bryozoa* have brought out some very interesting points bearing upon the earliest stages of *Fenestella*. The present paper deals with the development (astogeny) and morphology of *Fenestella*, and is based entirely upon calcified material from the Hamilton formation of Thedford, Ontario.† This material consists of numerous bases of *Fenestella* colonies. In these, the minutest details of internal structure are preserved with remarkable fidelity. The method of study has been the preparation of both thin and serial sections. The latter were obtained by slowly grinding down the bases and accurately drawing each stage as seen by reflected or in some cases by transmitted light. The specimens studied are in various stages of growth. Some represent the bases of adult colonies from which the adult (ephebastic) portion has been lost; others are minute bases, which in their growth never proceeded farther than the nepiastic stage. In these nepiastic

* In a former paper, a classification of the growth stages of the bryozoan colony was given, together with a general classification of the growth stages of any colony belonging to any group of organisms. The terms applicable to the growth stages of any colony are: *Nepiastic*, *neanastic*, *ephebastic*, and *gerontastic*, corresponding to the well-known terms *nepionic*, *neanic*, *ephebic*, and *gerontic*, applicable to the growth stages of the individual. Dr. Ruedemann has recently proposed the term *astogenetic* with reference to the colony, as the term parallel with *ontogenetic* with reference to the individual. The *astogenetic* stage of a colony, therefore, corresponds with the *ontogenetic* stage of an individual.

† This *Fenestella* is probably the form listed by Grabau as *Semicoscinium labiatum*.

colonies, the zoëcia emerge upon the surface; but in the older ones, the apertures of the zoëcia in the basal portion are submerged in a copious deposit of punctate sclerenchyma. In all cases, however, there has been no resorption of the earlier zoëcia, so that sections of the bases of ephebastic or gerontastic zoaria reveal the morphology of the earliest stages as faithfully as sections of a nepiastic colony. As an aid to the elucidation of the astogeny of *Fenestella*, the writer studied the astogeny of *Retepora phænicea*, a recent bryozoan morphologically very similar to the ancient *Fenestellas* and *Polyporas*.

In the writer's former paper on the development of Paleozoic Bryozoa, the term *protæcium* was introduced as designating the primary individual of the colony. In this sense, it would have the same signification as the term *ancestrula* of Jullien or *primary cell* of Hincks. In the Cyclostomata, as is well known, the first zoëcium surmounts a hemispherical base (*basal disc*), which serves as the point of attachment of the young colony to the substratum. This basal disc has been shown to be the calcified wall of the metamorphosed and histolyzed embryo (Barrois and others). It is believed by the present writer that the persistence of this structure (kathembryonic stage) in the ancient order of Cyclostomata is not without significance, especially in view of the fact, to be shown presently, that it is a conspicuous feature in the development of the ancient Cryptostomata and possibly of the Trepostomata (*Phylloporina corticosa*). The basal disc is probably the *true* first zoëcium. In the present paper, therefore, the term *protæcium* is restricted to the basal disc or its equivalent, and the superjacent portion of the primary cell is designated the *ancestrula*. In many recent Chilostomata, there seems to be no distinction of *protæcium* and *ancestrula*. This may mean that the extreme acceleration of these modern types has practically eliminated the *protæcium* from the ontogeny. In the ancient Cryptostomata, on the other hand, the *protæcium* greatly predominates over the *ancestrula*, which is often little more than an exaggerated aperture to the former. In any case, the ontogenetic stage of which the *protæcium* is the index is always present throughout the Ectoprocta, for by a degenerative metamorphosis they all give rise to a hemispherical kathembryo, from which the adult polypide arises by a sort of budding process. Furthermore, this kathembryo becomes invested with a calcareous or chitinous ectocyst, which is the first skeletal structure of the developing individual. The *protæcium* is therefore very closely analogous to the protegulum of brachiopods, the protoconch of cephalopods, etc.

DEVELOPMENT OF FENESTELLA.

The Protœcium.

Many well-preserved *Fenestella* bases show a minute circular pit on their basal surface. This can be seen only in colonies that were attached to a substratum which disappeared in the process of fossilization, leaving the basal surface of the colony free from all extraneous matter. Where the colony is still attached to the substratum, frequently the frond of another bryozoan, the circular pit can always be demonstrated by means of thin sections. This pit is the protœcium. As will be seen from the longitudinal sections (figs. 20, 36, 37, 59), the protœcium is separated from the substratum by a thin basal membrane. In such sections, this pit appears as a semi-circular object in the proximal portion of the colony. In transverse sections, it appears as a dark ring surrounded by concentric zones of punctate secondary sclerenchyma. That the protœcium has its own proper wall, similar to that of ordinary zoœcia, is shown by numerous sections (figs. 36-38, and 59). The diameter of the protœcium is from 0.4-0.6^{mm}, or about three or four times that of the ordinary zoœcia. In form and position it corresponds precisely to the basal disc of *Cyclostomata*, and there can be little doubt that it has the same morphological and developmental significance.

The Ancestrula.

The protœcium is surmounted by a tubular structure arising from the center of its distal surface. This is the ancestrula. In some of the earlier sections prepared by the writer, one of the primary buds was mistaken for the ancestrula, and its size and shape were therefore thought to be different from what was shown in later sections. It is considerably smaller than the primary buds, being both shorter and of less diameter. It seems altogether likely that the primary polypide never permanently ascended into the ancestrula as in the *Cyclostomata*. On the other hand, the ancestrula of *Fenestella* is far from being the homologue of the vestibule of ephebastic zoœcia. It is not built up of secondary deposits, but is composed of the same thin non-punctate substance as the proper wall of the protœcium and other zoœcia. The homology of the ancestrula of *Fenestella* is with the tubular primary zoœcium of the *Cyclostomata*. Figures 59 and 60 indicate the shape and appearance of the ancestrula as seen in the majority of properly orientated longitudinal sections,* and figures 10-13, 24, 43, and 54 in transverse sections.

* The zoœcium marked I, in figures 19 and 20, was at first thought to be the ancestrula, since it communicates freely with the protœcium. A careful study of the appearances possible in a series of longitudinal sections with

The Primary Buds.

Two lateral primary buds arise from the primary zoöcium (figs. 3-7, 21-23, 40-43). There is still some question as to whether these buds arise from the protoecium or from the ancestrula. The sections figured reveal all that can be expected. The question becomes one of interpretation and of analogy with recent Bryozoa. The proximal ends of the primary buds are in contact with the protoecium and are separated from its cavity by a very thin calcareous wall, which is frequently broken away (figs. 19 and 20). The appearance of this wall is well shown in figure 36. Figures 3-7 and 38-40, 42 show the intimate relation of the primary buds to the protoecium. From the analogy of recent Bryozoa, on the other hand, these buds might be expected to originate from the ancestrula. A median primary bud is not indicated by any of the sections. If it existed, it certainly arose from the ancestrula.

The size, shape, and position of the primary buds is beautifully shown in figures 38 and 39, and in the transverse sections. These buds are long and tubular, and diverge but slightly from the axis of the zoarium. There is no long vestibule as in ephebaestic zoöcia, but the whole aspect of the buds is that of a simple tubular zoöcium, quite similar to that of the Cyclostomata. There is also no indication of hemisepta or any other structures within the zoöcium.

Secondary Buds.

All buds of the second generation from the protoecium are designated secondary buds. The series of sections (figs. 1-16) seems to indicate that each of the primary buds produces a lateral and a median bud. The lateral buds are very clearly shown in such a position that they could have originated from no other source than from the primary buds (see especially figs. 5, 41, and 42). The median buds belong to the second tier of zoöcia. They are designated II_n and II_m in figure 13. The shape of the secondary buds is quite similar to that of the primary ones (figs. 37, 45, 59, and 60). Figure 50 is a drawing different assumed orientation has convinced the writer that the zoöcium in question is a primary bud. To test this, four different bases in which the protoecium and primary buds could be seen on the basal surface (in some cases only after slight etching) were sectioned in the direction $j-j$, figure 48, which had been determined by previous inspection of the basal surface, and marked by carefully drawing a fine line through the center of the protoecium and as nearly as possible between the primary buds. Every one of these sections has the appearance shown in figures 59, 60, and 45. It is therefore unlikely that figures 19 and 20 (which were orientated at random) represent the ancestrula. It is needless to state that only a very small proportion of the many sections prepared in this study are figured.

of a secondary bud, and may be compared with figure 53, which is a drawing of two zoecia of *Protocrisina* (after Ulrich), a cyclostomatous bryozoan from the Trenton. The resemblance is too striking to need further emphasis. No internal zoecial structures have been observed in the secondary buds.

Tertiary and Later Buds.

One bud of the third generation from the ancestrula occupies a position in the first tier of zoecia, diametrically opposite the ancestrula (*III*, figs. 6-13, 24, 26, 43, 54-58). The shape of this bud is well shown in figures 37, 45, 59, and 60. There is no means of telling from which of the two secondary buds this tertiary one is derived. It may have originated now from one, now from the other. In figure 43, it is rather more intimately associated with 32, which was in turn derived from the right lateral primary bud. Figure 13 indicates that each of the secondary buds gives rise to a median bud lying in the second tier of zoecia.

Ascending the axis of the zoarium (figs. 17-20, 36-39), there is exhibited a series of zoecia very symmetrically arranged about the axis. In transverse sections, above the level of *y*, figure 17, these present a peculiar star-shaped appearance seen in figures 15, 16, and 58, as well as in figure 61 of the writer's former paper. The order of budding of these later zoecia cannot be determined, although the writer has devoted a large amount of time and study to this point. It is probable that the order of budding in these later generations is without significance. An important point shown by the sections, however, is the shape and size of these zoecia. This is best seen in figures 17 and 38. The zoecia are tubular, but somewhat less elongate than the earlier ones. It is not until the zoarium begins to expand into its characteristic infundibular form that the zoecia assume the shape normal to *Fenestella*. Figure 51 shows a row of zoecia from the neanastic region (base of the cone) of the specimen represented in figure 38. For comparison with this is inserted figure 52, showing a specimen of *Fenestella acmea* from the Waldron shale of Tarr Hole, Indiana. The resemblance is striking. The adult zoecia of the Thedford *Fenestella* are shown in figure 49.

Discussion and Conclusions.

The morphological element of the bryozoan colony which corresponds to the primitive integument of Mollusca, Brachiopoda, etc. (that is, to the protoconch, protegulum, etc.), is the *protæcium*, or basal disc, of the primary individual of the colony. The protæcium is the calcareous or chitinous wall of

the kathembryo. In *Fenestella* it is very large and in every way similar to the protœcium (basal disc) of the Cyclostomata. The ancestrula is the tubular superstructure of the primary individual. It is a simple, undifferentiated, tubular zoœcium. The earlier formed zoœcia (nepiastic zoœcia) of the *Fenestella* colony differ markedly in shape and size from later formed (neanastic and ephebastic) zoœcia. In every feature in which they depart from the ephebastic zoœcia of *Fenestella* they approach the ephebastic zoœcia of the Cyclostomata.

From these observations, it may be reasonably concluded that *Fenestella* as well as the entire order of Cryptostomata is derived from the Cyclostomata. Certain other general conclusions, more or less speculative, are suggested by a consideration of the probable significance of the protœcium and ancestrula.

The meaning of the degenerative metamorphosis of Bryozoa has always been a puzzle to students of this class. The striking analogy of this metamorphosis to the degeneration of an ordinary polypide and production of a brown body, together with the nearly identical life history of the regenerating polypide or of ordinary buds and the primitive polypide issuing from the kathembryo, have more than once led to the suggestion that the primitive polypide is in the true sense a bud. The writer is inclined to hold this view. Assuming, therefore, that the primitive polypide is a bud, the following suggestions may be made in regard to the significance of the metamorphosis and of the resulting protœcium:

1. In the primitive bryozoan, there was no histolysis of the larval organs. The development was direct and resulted in a primitive zoœcium and polypide.

2. This primitive zoœcium was hemispherical in shape and possessed a simple aperture in the center of its upper surface. Some ancient types of Cyclostomata retain nearly such a form of zoœcium (*Stomatopora* of the Trenton, especially *S. turgida*).

3. This primitive zoœcium might now give rise to a linear adnate series of zoœcia, as in *Stomatopora*, or to a series of superposed zoœcia, as in the Trepotomata. By variations of zoarial habit based upon one or the other of these fundamental plans of budding all existing types of Bryozoa could have been produced.

4. In accordance with the law of tachygenesis, later in the history of the bryozoan group a tendency toward concentration of the early stages in development would arise. In any colony the tendency to degenerate may be supposed to have applied to the primitive polypide as well as to later ones, and finally to have become an invariable part of its life history. By the continued operation of the law of tachygenesis, the life history of the first polypide became so abbreviated as to be

represented only by its degenerative stage, that is, by its latest growth stage, all the earlier growth stages having been crowded out or back into the larval stage.

In accordance with this interpretation of bryozoan development, the large size of the protœcium in ancient types is explicable and is thought to be due to a less degree of acceleration, the calcification of the zoœcial wall of the primitive individual being allowed to proceed nearly to completion before the second zoœcium was superposed upon it. The probability that the first polypide remains in the protœcium in *Fenestella*, instead of ascending into the ancestrula as in modern Cyclostomata, may indicate a still more primitive condition. The relations of the protœcium and ancestrula in the Cyclostomata and in *Fenestella* suggest the normal relation of superposition of the zoœcia in the Trepostomata. It is not without interest to find evidence, in the development of Paleozoic Bryozoa, of the fundamental relationship of these great groups. Ulrich (Geol. Surv. Illinois, vol. viii) has already suggested such a relationship on the ground of the resemblances of such types as the early Fenestellas, *Phylloporina* and *Protocrisina*. The evidence presented by these adult types is greatly strengthened by the striking parallelism of the nepiastic stages of *Fenestella* with the series of adult types named above.

Paleontological Laboratory, Indiana University,
June, 1905.

EXPLANATION OF PLATES.

*Description of Figures.**

Letters having the same meaning for all the figures:—

- a, b, c, d, e*, primary carinæ (except figs. 17, 24, 47, and 48).
- f*, fenestrulæ.
- k*, carina.
- o*, protœcium.
- s*, substratum of bryozoan colony.
- z, z'*, etc., zoœcia of generations later than the primary zoœcia.
- A*, ancestrula.
- I*, primary bud.
- II*, bud of second generation, that is, derived from a primary bud.
- III*, bud of third generation.
- 2*, left lateral bud.
- 3*, right lateral bud.
- 23*, right lateral bud of the second generation, derived from a left lateral primary bud.
- 32*, left lateral bud of the second generation, derived from a right lateral primary bud.

* All drawings except figures 1-16 were made with the camera lucida. Figures 30-32 are after Barrois, and figure 53 is after Ulrich. All the specimens of *Fenestella* are from Thedford, Ontario.

PLATE V.

- FIGURES 1-16.—Transverse serial sections of a *Fenestella* base. These sixteen sections represent 1^{mm} thickness of rock.
- FIGURES 1, 2.—Protoecium (cf. figs. 40, 41, 31-35).
- FIGURE 3.—Section in the plane of $a-a'$, figure 47, cutting the proximal ends of the primary buds and the buds of the second generation (secondary buds) (cf. fig. 42).
- FIGURES 4, 5.—Successively higher sections.
- FIGURE 6.—Section in plane of $a'-a'$, figure 47, cutting the proximal end of the tertiary bud (cf. fig. 43).
- FIGURES 7-12.—Successively higher sections between the planes of $a'-a'$ and $c-c$, figure 47, showing the development of the initial buds. Figures 10-12 cut the aperture of the ancestrula (cf. fig. 24, with fig. 12).
- FIGURE 13.—Section cutting the proximal ends of buds of the second tier (*II*₁, *II*₂, *III*₁, *III*₂, and *III*₃) (cf. fig. 26).
- FIGURE 14.—Section just cutting the distal end of the aperture of the ancestrula.
- FIGURES 15, 16.—Assumption of the star-shaped arrangement of zoecia, characteristic of the paranepiastic stage of *Fenestella*.

PLATE VI.

- FIGURE 17.—Longitudinal section of a *Fenestella* base cutting in the plane of $e-e$, figure 47, and $a-a$, figure 48. This section passes through the edge of the protoecium and misses the ancestrula entirely. b, b' , buds of the second tier. At z and z' the zoecia are vertically above each other; at z'' , z''' they alternate, and at the top of the figure they lie side by side. $\times 17$.
- FIGURE 18.—Longitudinal section cutting still more excentrically than that shown in figure 17, probably in the plane of $b-b$, figure 48. This misses the protoecium and ancestrula entirely, but their relative position is shown at o and A . The vertical alignment of zoecia is shown at $z-z'$ and the ordinary arrangement, on either side of the carina, at z'' . The bifurcation of a primary branch is shown at $g-h$ (between z'' and g, h). In each new branch, the zoecia first alternate and later lie side by side. Normal arrangement shown at $k' k''$. $\times 17$.
- FIGURE 19.—Longitudinal section cutting in the plane of $c-c$, figure 48. The section cuts a row of zoecia ($z'-z'$) nearly longitudinally. $\times 17$.
- FIGURE 20.—Section in nearly the same plane as in figure 19 ($d-d$, figure 48). This section was orientated by polishing and etching the basal surface of the colony and marking the position of the protoecium and primary buds. The section was then ground as nearly as possible in the marked direction. A primary bud is very clearly shown (*I*). $\times 17$.
- FIGURE 21.—Transverse section in the plane of $a-a$, figure 47. The primary buds are very distinct. $\times 17$.
- FIGURE 22.—Similar section of another specimen, cutting the proximal end of the ancestrula. $\times 17$.
- FIGURE 23.—Transverse section of a very slender base. Section in about the same plane as 22. $\times 17$.
- FIGURE 24.—Section in the plane of $b-b$, figure 47. Ancestrula very distinct. $\times 17$.
- FIGURE 25.—Longitudinal section of a base from which the substratum was absent. $\times 17$.
- FIGURE 26.—Transverse section in the plane of $d-d$, figure 47, showing the proximal ends of two buds of the second tier (z, z') (cf. fig. 13). $\times 17$.
- FIGURE 27.—Protoecium and ancestrula of *Retepora phanicea* from St. Vincent's Gulf, Australia. $\times 27$.
- FIGURE 28.—Ancestrula and three primary buds (1, 2, 3) of *Retepora phanicea*. $\times 29$.
- FIGURE 29.—Profile view of protoecium and ancestrula of another specimen of *Retepora phanicea*. $\times 27$.

- FIGURE 30.—Protœcium, ancestrula, and primary bud of *Tubulipora*. After Barrois. $\times 27$.
 FIGURE 31.—Same; seen from the under surface. $\times 27$.
 FIGURE 32.—Ancestrula and primary bud of *Schizoporella*. $\times 33$.
 FIGURE 33.—Protœcium and primary zoœcia of *Phylloporina corticosa* from Cannon Falls, Minnesota. $\times 17$.
 FIGURE 34.—Protœcium of *Polypora* from the Lower Helderberg of Indian Ladder, New York. $\times 28$.
 FIGURE 35.—Protœcium of *Thamniscus* from the Upper Coal Measures of Kansas. $\times 17$.

PLATE VII.

- FIGURE 36.—Longitudinal section of *Fenestella*, in the plane of *f-f*, figure 48. $\times 17$.
 FIGURE 37.—Longitudinal section in the plane of *g-g*, figure 48. $\times 17$.
 FIGURE 38.—Longitudinal section in the plane of *h-h*, figure 48. This section shows remarkably well the shape of the nepiastic zoœcia. $\times 17$.
 FIGURE 39.—Longitudinal section in the plane of *i-i*, figure 48. $\times 17$.
 FIGURE 40.—Transverse section in the plane of *a-a*, figure 47. Shows the primary buds (2, 3). $\times 17$.
 FIGURE 41.—Transverse section of another specimen in which the primary and secondary buds have a rather unusual arrangement. $\times 17$.
 FIGURE 42.—Transverse section in the plane of *a'-a'*, figure 47 (cf. fig. 5). Same specimen as figures 54-58. $\times 17$.
 FIGURE 43.—Transverse section in the plane of *b-b*, figure 47. Shows the proximal end of the tertiary bud (cf. fig. 10). $\times 17$.
 FIGURE 44.—Probable interpretation of figure 39. Section in the plane of *i-i*, figure 48.
 FIGURE 45.—Semidiagrammatic drawing of a longitudinal section (in the plane of *j-j*, fig. 48) of a specimen showing the ancestrula and two zoœcia, probably one of the secondary buds and a tertiary bud (*II, III*). $\times 17$.
 FIGURE 46.—Semidiagrammatic drawing of a longitudinal section (in the plane of *k-k*, fig. 48) of the ancestrula and protœcium of another specimen. $\times 17$.
 FIGURE 47.—Semidiagrammatic drawing from figure 37, to show the position of transverse sections.
 FIGURE 48.—Semidiagrammatic drawing from figure 43, to show the position of longitudinal sections.
 FIGURE 49.—Ephebastic zoœcia of *Fenestella*. Specimen from Thedford, Ontario. $\times 17$.
 FIGURE 50.—Nepiastic zoœcium of *Fenestella*. Specimen from Thedford, Ontario. $\times 17$.
 FIGURE 51.—Neanastic zoœcia of *Fenestella*. From the proximal portion of the cone of the same specimen as that shown in figure 38. $\times 17$.
 FIGURE 52.—Ephebastic zoœcia of *Fenestella acmea* from the Waldron shale of Tarr Hole, Indiana (cf. fig. 51). $\times 17$.
 FIGURE 53.—Ephebastic zoœcia of *Protocrisina exigua* Ulr. from the Trenton limestone of Montreal, Canada (cf. fig. 50). After Ulrich. $\times 18$.
 FIGURES 54-58.—Serial sections of a *Fenestella* base. Same specimen as that shown in figure 42, figure 54 being the next section above. Figures 55-58 are successively higher sections. $\times 17$.
 FIGURE 59.—Longitudinal section (in the plane of *j-j*, fig. 48) of a *Fenestella* base, showing the shape of the ancestrula most often seen, and three nepiastic zoœcia (*II, III, z'*). $\times 17$.
 FIGURE 60.—Semidiagrammatic drawing from figure 59.

ART. XXI.—*Age of the Monument Creek Formation*;* by
N. H. DARTON.

THIS contribution is an account of additional evidence as to the Oligocene age of the Monument Creek formation, or at least of its upper member, afforded by the discovery of Titanotherium and other fossil bones at several localities.

On the high divide between the Platte and Arkansas drainage basins, at the foot of the Rocky Mountains, there is an extensive deposit of sands, gravel and clay to which F. V. Hayden gave the name of Monument Creek group.† This observer recognized the fact that the group overlies the Laramie formation unconformably, but apparently he included in its lower portion more or less of the beds later separated, as the Arapahoe and Denver formations in the Denver region. The opinion was held that it was of early Tertiary age, but no precise correlation was suggested. In 1873, Prof. E. D. Cope examined a portion of the deposit and found a few bones in regard to which he made the following statement :‡

"The age of the Monument Creek formation in relation to the other Tertiaries not having been definitely determined, I sought for vertebrate fossils. The most characteristic one which I procured was the hind leg and foot of an *Artiodactyle* of the Oreodon type, which indicated conclusively that the formation is newer than the Eocene. From the same neighborhood and stratum, as I have every reason for believing, the fragment of the *Megaceratops coloradoensis* was obtained. This fossil is equally conclusive against the Pliocene age of the formation, so that it may be referred to the Miocene until further discoveries enable us to be more exact."

Doubtless Professor Cope regarded the fauna as belonging in the White River group, which is now generally considered to be Oligocene. He added nothing regarding the precise locality, or stratigraphic position of the fossils. So far as I can find, no further paleontological evidence has since been offered, regarding the age of the formation. A brief account of the Monument Creek formation was given by G. H. Eldridge, in the "Geology of the Denver Basin."§ The true stratigraphic limits of the formation in relation to the underlying

* Published by permission of the Director of the United States Geological Survey.

† Preliminary field report of U. S. Geological Survey of Colorado and New Mexico, 1869, p. 40.

‡ [7] Annual Report of the United States Geological and Geographical Survey of the Territories, embracing Colorado, Report for 1873, by F. V. Hayden, p. 430.

§ United States Geological Survey, Monographs, vol. xxvii, pp. 252-254.

Laramie, Arapahoe and Denver formations were recognized, and it was shown that the formation consists of two distinct members separated by a well-defined break in deposition. The lower member lies on an uneven floor of Denver formation at the north and Laramie to the southeast. It displays "marked regularity in the succession of its beds, excepting at the base, where, owing to the uneven floor, the material varies from conglomerate through sandstone to arenaceous shale. A short distance above the base are two broad bands of green shale separated by one of pink and capped by a fine grit, or sandstone, which is soft and friable and easily disintegrates." The thickness is estimated to be about 900 feet. The sandstones and grits of the lower member are mostly of granite debris. The upper member consists of sandstones and shales, with numerous beds of conglomerate, and between the two there are local deposits of rhyolitic tuff, in places 40 feet thick, which are quarried extensively for building stone near Castle Rock. In the lower part of the upper member many fragments of this rhyolitic tuff occur, a feature which is notably displayed in the breccia and conglomerate capping the butte known as Castle Rock. The thickness of the upper member is estimated by Eldridge at about 400 feet. In portions of the area, I have observed that in the lower member there are extensive deposits of massive clay, very similar in appearance and properties to the fullers earth which is characteristic of the Chadron formation, or Titanotherium beds, of the White River group in the Big Bad Lands of South Dakota and elsewhere.

In the general résumé of the geology in the Monograph on the Denver Basin,* Mr. Emmons suggests that the vertebrate remains of Miocene age probably were from the lower member of the formation and that the upper member might be correlated with the Pliocene. This suggestion was based on the fact that the uppermost Tertiary deposits in the eastern portion of Colorado are of Pliocene age, and in the region north of the Platte River they lie unconformably on White River beds. Mr. Emmons recognized the fact that these beds differ somewhat from Monument Creek beds in character, yet this could be explained by the proximity of the Monument Creek formation to shore lines along the mountain front.

Two years ago, while examining the southern portion of the Monument Creek area, I obtained from the conglomerate four miles northwest of Calhan, the distal end of a large humerus which Dr. F. A. Lucas has identified as Titanotherium. This conglomerate is the upper member of the formation and caps a long line of buttes and extensive plateaus. A number of

* Loc. cit., p. 39.

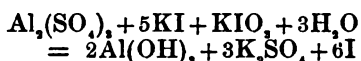
bones have also been collected for me along the valley of Cherry Creek, half way between Castle Rock and Elizabeth, consisting mainly of bones of titanotherium. They were obtained at many localities and all from the sandstones of the upper member of the formation. A fragment of a lower jaw of titanotherium was the most distinctive fossil obtained. It was found in the upper beds, at Kaumpfer's ranch, 7 miles southwest of Elizabeth. In Wild Cat Canyon, 6 miles west-by-south of Elizabeth, were found fragments of a jaw and the distal ends of a titanotherium tibia and humerus. Portions of a lower jaw of hyracodon, apparently *nebrasensis*, were found in a well at Anderson's place 6 miles south-southwest of Elizabeth, together with various turtle bones. All of this material appears to have been obtained from the upper beds and it correlates these beds with the Chadron formation of the White River group, or Oligocene. No evidence was obtained as to the age of the lower member, but the fullers earth, as before mentioned, is similar to that which is so characteristic in other areas. The presence of the unconformity between the upper and lower members suggests that the latter may be of Wasatch or Bridger age. The nearest locality to the Monument Creek area, at which Oligocene deposits occur in eastern Colorado, is in the vicinity of Akron and Fremont's Butte, where titanotherium remains occur in abundance. Farther north, in the region about Pawnee Buttes, there are well-known localities of the titanotherium and overlying beds. In the low intervening area, east and southeast of Denver, Oligocene deposits are absent, but it is probable that originally they extended continuously from the vicinity of Akron to the foot of the Rocky Mountains in the Monument Creek area. There is much evidence throughout the Great Plains region that the Oligocene deposits were originally of wide extent, for outliers occur along the mountain slopes and in many widely separated areas. They have been subjected to extensive degradation in Miocene, Pliocene and later times and probably removed from large districts, especially in the wider valleys. In my recent report on the Great Plains,* there is given a map showing their present distribution and probably former great extent.

* United States Geological Survey, Professional Paper No. 32, pl. xliv.

ART. XXII.—*The Iodometric Determination of Aluminium in Aluminium Chloride and Aluminium Sulphate*; by S. E. MOODY.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxviii.]

A PROCESS for the gravimetric determination of alumina in salts of aluminium has been described by Stock,* who bases the method upon the reaction represented by the following equation :



This equation would show that iodine is liberated when potassium iodate and potassium iodide are together added to a solution of aluminium sulphate. It was found, however, that in the action of the iodide-iodate mixture upon a solution of potassium alum, only about two-thirds of the iodine corresponding to the aluminium salt is accounted for; and this suggests that the reaction is not completed according to the equation, and that the precipitate formed is not the simple hydroxide. Upon ignition the precipitate yields, however, the total amount of alumina present; and, since the character of the precipitate is good, the process is easily managed and gives, as Stock has said, an excellent gravimetric method for the determination of alumina.

Taking aluminium chloride, $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$, and proceeding in the same manner, similar results are obtained, and after dissolving the precipitate in sulphuric acid and adding silver nitrate to the dilute solution, a decided precipitate of silver chloride is observed, which upon washing, drying and weighing is found to be about one-third of the amount of that substance corresponding to the original aluminium chloride. This indicates that it is an oxychloride which is formed on the addition of potassium iodide and iodate; moreover, upon removing by sodium thiosulphate the iodine first set free in the action and allowing the mixture to stand, progressive hydrolysis takes place as shown by the return of color due to iodine, and this change can be still further hastened by heating after adding an excess of sodium thiosulphate to take up the iodine as liberated. The attempt was made, therefore, to complete the reaction between the iodide-iodate mixture and the aluminium chloride, or alum, by heating the solution in a Voit flask through which steam or, still better, hydrogen was passed, as an aid in the transfer of the iodine liberated to a receiver

* Ber. Dtsch. Chem. Ges., 1900, xxxiii, i, p. 548.

charged with a solution of potassium iodide. The iodine collected was titrated with $\frac{n}{10}$ sodium thiosulphate.

Table I gives results obtained by this method. The details of the experiments in which steam was used as an agent to force the iodine over are given in section A, while those of the experiments in which hydrogen was employed are indicated in section B.

TABLE I.

Approx. $\frac{n}{10}$ Aluminium chloride solution. cm ³ .	HIO ₃ . gram.	KI. gram.	Time in minutes. A	Approx. $\frac{n}{10}$ Na ₂ S ₂ O ₃ . cm ³ .	Al ₂ O ₃ calculated gram.	Diff. gram.
25	0.3	1.0	25	25.05	0.0427	-0.0007
25	0.3	1.0	90	25.15	0.0428	-0.0006
B						
25	0.3	1.0	20	25.05	0.0427	-0.0007
25	0.3	1.0	15	25.10	0.0428	-0.0006
25	0.3	1.0	15	25.00*	0.0426	-0.0009
25	0.3	1.0	15	25.00*	0.0426	-0.0009

In each of these experiments the iodide-iodate mixture was made by exactly neutralizing iodic acid with potassium hydroxide, adding a minute crystal of the iodic acid, introducing the potassium iodide in solution and taking up with a drop or two of sodium thiosulphate the iodine set free. This mixture was put into the Voit flask together with the aluminium chloride, and the whole was heated in the current of steam or hydrogen.

Applying the process to a solution of potassium alum the results recorded in the following table were obtained.

TABLE II.

Approx. $\frac{n}{10}$ Aluminium potassium alum. cm ³ .	KIO ₃ . gram.	KI gram.	Time in minutes.	Approx. $\frac{n}{10}$ Na ₂ S ₂ O ₃ . cm ³ .	Al ₂ O ₃ calcu- lated. gram.	Al ₂ O ₃ found. gram.	Diff. gram.
25	0.3	1.0	30	24.55	0.0410	0.0414	-0.0004
25	0.3	1.0	30	24.60	0.0411	0.0416	-0.0005
25	0.3	1.0	25	24.50	0.0409	0.0414	-0.0005
25	0.3	1.0	30	24.70	0.0413	0.0416	-0.0003
25	0.3	1.0	35	24.50	0.0409	0.0415	-0.0006
25	0.3	1.0	30	24.55	0.0410	0.0415	-0.0005
25	0.3	1.0	25	24.50	0.0409	0.0415	-0.0006

* New standard.

In Table III are shown results of the application of the process to an ammonium alum.

TABLE III.

Approx. $\frac{n}{10}$ Ammonium alum. cm ³ .	KIO ₃ . gram.	KI. gram.	Time in minutes.	Approx. $\frac{n}{10}$ Na ₂ S ₂ O ₃ . cm ³ .	Al ₂ O ₃ calculated gram.	Diff. gram.
25	0·3	1·0	20	25·20	0·0429	+0·0007
25	0·3	1·0	15	25·17	0·0429	+0·0007
25	0·3	1·0	20	25·10†	0·0427	+0·0005
25	0·3	1·0	25	25·20†	0·0429	+0·0007
25*	0·3	1·0	12	25·70†	0·0421	—0·0001
25*	0·3	1·0	12	24·65†	0·0420	—0·0002
25	0·3	1·0	20	25·20†	0·0430	+0·0008
25	0·3	1·0	25	25·15†	0·0429	+0·0007
25	0·3	2·0	25	25·20†	0·0430	+0·0008
25	0·3	2·0	20	25·15†	0·0429	+0·0007

These results proved to be too high and led to the conclusion that the ammonium sulphate was acted upon by the iodic mixture, liberating an additional portion of iodine. Experiments with ammonium sulphate verified the supposition, and the process is, therefore, less accurate in the presence of ammonium salts. In fact, ammonium sulphate in the amounts taken may be completely hydrolyzed in the course of three hours, about one-half of the iodine liberated by the sulphuric acid formed in the hydrolysis being available for estimation under the conditions of the foregoing determinations. When, however, the distillate is collected in a solution of potassium iodide containing sufficient acid to combine with the ammonia volatilized, iodine is liberated in amount equivalent to the entire quantity of sulphates present, and may be titrated with sodium thiosulphate.

The reaction between iodine and ammonia in alkaline solution, and the hydrolysis of ammonium salts, are undergoing further investigation by the writer.

The attempts to obtain a complete reaction by heating the mixture in a pressure bottle showed that the results of this procedure are low, although but slightly deficient, and cannot be used for estimating correctly the amount of aluminium salt in the solution.

The following method can be recommended as one giving constant results which correspond closely with the gravimetric

* Liquid in Voit flask not clear.

† New standard.

‡ New standard.

determinations and the theoretical amount of alumina in neutral aluminium chloride, sulphate, or alum, little time being necessary for a single determination :

Measure 25^{cm}³ of the approximately $\frac{n}{10}$ solution of the neutral aluminium salt to be analyzed into a Voit flask and to this add a mixture of 10^{cm}³ of a solution of neutral potassium iodate (30 grms. to a liter) and 1.0 gm. potassium iodide. Pass a current of hydrogen through the liquid and heat for fifteen to twenty-five minutes, or until the solution is nearly colorless, collecting the iodine liberated in a Drexel flask, about half full of water, in which 3 grms. of potassium iodide is dissolved. Titrate with sodium thiosulphate the iodine in the Drexel flask and that which remains in the solution in the Voit flask, and calculate the amount of alumina, Al₂O₃, corresponding to the iodine, 6I, liberated.

The writer wishes to thank Professor F. A. Gooch for friendly assistance during this investigation.

ART. XXIII.—*The Secondary Origin of Certain Granites*;
by REGINALD A. DALY, Ottawa, Canada.

[Published by permission of the Chief Commissioner for Canada, International Boundary Surveys.]

CONTENTS.

General thesis of the paper.

A. The Sills of the British Columbia (International) Boundary.

The Moyie Sill.

Field Hypothesis.

B. Occurrences in Minnesota.

(a) Pigeon Point.

(b) Governor's Island.

(c) Lake Superior islands and Logan sills.

(d) Cook County, Lake County and other localities.

C. The Sudbury intrusive sheet.

Synthetic discussion.

Magmatic assimilation.

Summary.

Asymmetry of the intrusive bodies.

Magmatic Differentiation.

General Application.

General thesis of the paper.—Igneous rocks originate in magmas. The discovery of the laws governing the immediate derivation of such rocks from their parent magmas is, therefore, not the final aim of the geologist. He is logically compelled to refer rocks themselves to the yet more fundamental problem of the origin of igneous magmas. Whence come the raw materials of basalt, gabbro, porphyry or granite?

One of the earliest answers to this question has been gradually assuming a systematic statement in the form of the "assimilation theory". This theory holds that some igneous rocks are derived from the compound magmas formed by the local fusion of solid rock in molten rock of a different chemical composition. The process can be imitated in the laboratory furnace, and has certainly operated on many igneous contacts in nature. Yet one of the very latest utterances of one of the world's greatest petrologists reads thus: "The untenability of the 'assimilation' or fusion theory I regard as definitely proved."* On the other hand, a no less well known authority claims assimilation on a large scale as a necessary stage in the preparation of the Christiania granite.† Brögger and many of his followers hold that the contact phenomena of this granite show that the assimilation theory breaks down even when applied to a most favorable case.

* "Die Unhaltbarkeit der 'Assimilations'- oder Einschmelzungs-Theorie betrachte ich als endgültig bewiesen."—J. H. L. Vogt, *Die Silikatschmelzungen*, Part II., Christiania, 1904, p. 225.

† F. Loewinson-Lessing, *Comptes Rendus*, 7th Session, International Geological Congress, 1899, p. 369.

This divergence of view is, of course, due to the lack of definite knowledge of the vital conditions controlling the activities of such an intrusive body as the Christiania granite. The study of its accessible contacts can, of itself alone, furnish neither proof nor disproof of the doctrine of wholesale assimilation. Without the aid of other geological data the attempt to solve the problem is like the attempt to produce graphically a complex curve of which but two points are known and fixed. Deep-seated assimilation about any magma chamber can only be finally discussed and evaluated if the complete form of the chamber and the complete composition of its rock-filling are at least tolerably known.

The present paper furnishes a brief discussion of a number of cases where it is believed that magmatic assimilation on a comparatively large scale has taken place. It is believed, further, that the geological conditions in these cases supply elements generally untouched in earlier discussions of the doctrine. The original magma had the composition of a gabbro intruded in the manner of sills; the invaded formations are ancient sandstones, both normal and feldspathic, with associated argillites or schists; the invaded formation, in every case, is more acid than the gabbro; the product of assimilation is always a granite graduating into granophyre. The acid magma is believed, however, to have been derived indirectly from the compound magma of assimilation through a systematic kind of differentiation. The primary cause of the differentiation is referred to the perfect or nearly perfect density stratification of each magmatic chamber.

The result of the investigation has been to confirm the writer's general theoretical conclusions on the subject of assimilation where it was necessarily introduced among the tests of the hypothesis of magmatic stoping*. Assimilation and differentiation are not antagonistic processes; both of them are involved in the secondary origin of some granites.

A. The Sills of the British Columbia (International) Boundary.

During the field season of 1904 the writer developed a geological structure section along the 49th parallel of latitude between Port Hill, Idaho, and Gateway, Montana, the two points where the Kootenay River crosses the boundary line between Canada and the United States. It was found that the mountains traversed by the section are for the most part composed of two very thick siliceous sedimentary formations which, in all probability, are of pre-Cambrian age. The two are conformable.

The lower formation has been called the Creston quartzite. It is a remarkably homogeneous, highly indurated light-to medium-gray sandstone, generally thick-platy in structure but

* This Journal, xv, 269, 1903, and xvi, 107, 1903.

occasionally interrupted by thin intercalations of argillaceous material. The formation is generally composed of nearly pure quartz with a little mica, but some bands are feldspathic to a notable extent. The total thickness of the formation is at least 9900 feet in the vicinity of Port Hill; its base was not directly observed.

Immediately overlying the Creston quartzite is the conformable Kitchener quartzite, composed of about 7400 feet of a highly ferruginous indurated sandstone. This formation is, in the field, distinguished from the Creston quartzite not only by the rusty color of the outcrops but also by a relatively thinner bedding and a greater proportion of micaceous cement, once somewhat argillaceous. Individual beds of the Kitchener quartzite are charged with detrital feldspar, but the formation as a whole is essentially composed of cemented quartz grains.

Dark-colored red, brown, and gray shales with thin intercalations of gray quartzite conformably overlie the Kitchener quartzite. The series, totalling 3200 feet in thickness, has been grouped under the name of the Moyie argillite. This formation appears but twice in the section and then only in comparatively small areas.

This great group of formations, from end to end of the section, has been mountain-built. A few open folds broken by faults appear in the eastern half of the belt, but the deformation has generally been due to the tilting of monoclinical blocks separated by strong normal faults and, more rarely, by thrusts. The tilting ranges though all angles up to verticality, but the average dip is less than forty-five degrees. In consequence of the deformation and subsequent denudation the edges of some 20,000 feet of well-bedded ancient sediment are now exposed for study. There have also come to light a number of thick sills of gabbro intruded at various horizons into the Kitchener quartzite and the upper part of the Creston quartzite. The intrusion and crystallization of the gabbro is believed to have taken place before the upturning of the sedimentaries. The faulting and tilting has repeated the outcrops of certain of the sills. One of the thickest of them has, along with the quartzites, been warped into one of the rare synclinal folds. The thickness of the sills varies from 100 feet to more than 2500 feet.

The main mass of each sill was uniformly found to consist of a hornblende gabbro with essential green (primary) hornblende and plagioclase (labradorite to anorthite, the latter in the cores of occasionally zoned feldspars). Accessory quartz, often in considerable amount, always accompanies the other accessories, which are titanite, titaniferous magnetite, and apatite with often a little biotite and sometimes a little orthoclase in addition. Epidote and chlorite are the principal secondary

minerals. The structure of the rock is typically hypidiomorphic-granular.

Already in those sills that range from 400 to 500 feet in thickness, the gabbro is acidified near its upper contact. The change from the normal composition is seen in the great increase of biotite, orthoclase, microperthite and interstitial quartz.

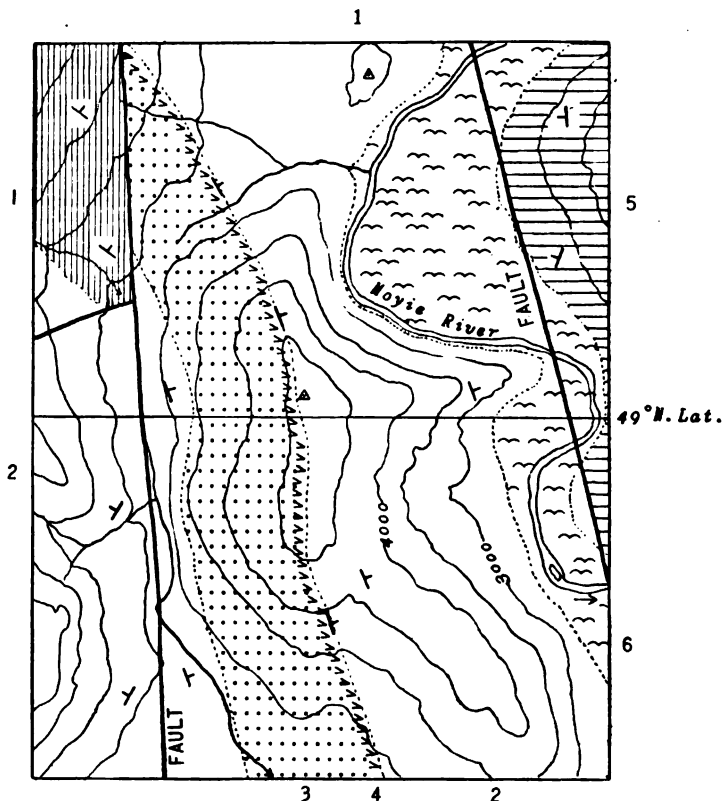


FIG. 1. Map of Moyie Sill, taken from plane-table sheet of the International Boundary Commission. 1. Moyie argillite. 2. Kitchener quartzite. 3. Hornblende gabbro sill. 4. Acidified (granite) zone of sill. 5. Creston quartzite. 6. Alluvium. Conventional sign for strike and dip. Scale: one inch = about one mile.

Biotite and quartz then assume the proportions of essential minerals. The quartz is characteristically in poikilitic relation to all the other constituents except orthoclase and microperthite, with which it is in true micrographic intergrowth. From this micropegmatite-bearing phase of the intrusive there is a gradual transition to the normal gabbro which thus composes the lower three-fourths or four-fifths of the sill.

The Moyie Sill.—The acidification of the upper zone of the gabbro being generally in a direct ratio to the strength of the sill, the phenomenon is specially marked in the greatest of all the intrusions. On account of its importance both in size and character, this rock-body is called the "Moyie Sill," the name referring to its situation on the Moyie River. A map and section of this sill are given in figs. 1 and 2, which illustrate one of the fault-blocks so characteristic of this part of the Boundary belt.* The sill is rather more than 2500 feet in thickness. It follows the bedding of the Kitchener quartzite, which here dips about sixty degrees to the eastward. The intrusive mass is seen to be cut off at its northern end by a master-fault which has dropped the Moyie argillite down into contact with the

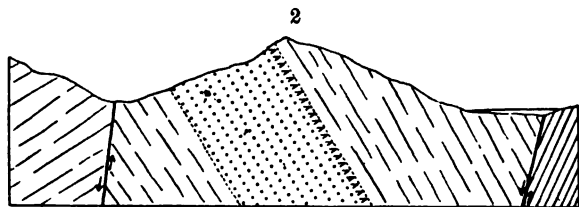


FIG. 2. Section of Moyie Sill, along line of the International Boundary.

gabbro. This faulting is believed to have occurred after the sill-intrusion. There is a complete lack of contact metamorphism in the argillite where it adjoins the gabbro.

Since the Moyie sill, throughout the six miles of linear outcrop studied, is in intrusive contact with the Kitchener quartzite alone, the other sedimentary formations need not here be described in detail. The Kitchener quartzite is, on the whole, a homogeneous terrane. On a fresh fracture the rock is seen to be a fine-grained, vitreous, light to darkish gray, well-bedded but tough, metamorphic sandstone, splitting with some readiness along the darker colored layers. The rusty color of the joint-surfaces and bedding planes is due to the leaching out and subsequent deposition of the iron contained in the pyrite, magnetite, etc., disseminated through the rock.

Under the microscope the rock is always seen to be essentially a fine-grained aggregate of interlocking quartz grains, seldom showing any direct traces of their detrital origin. The quartz mosaic is, in every thin section, shot through with abundant crystals of biotite which is often developed in phenocryst-like individuals occasionally as much as one centimeter in diameter. Sericitic muscovite is seldom absent as an essential, and sometimes rivals the biotite in abundance. Only

* All the line-drawings used in illustration of this paper have been made for the most part by the aid of a typewriter, provided with a few special keys. The machine permits of a great saving of time in the preparation of the manuscript drawings. Cf. this Journal, vol. xix, 1905, p. 227.

rarely is feldspar essential; in one slide it seems to compose ten to fifteen per cent of the rock. So far as observed, the feldspar of the staple quartzite is orthoclase. No sodiferous mineral has been certainly determined in the rock. Epidote, zoisite, titanite, magnetite, leucoxene, pyrite and zircon, besides chlorite, secondary after biotite, are the other, always subordinate, constituents.

In marked contrast to the normal quartzite is the rock collected at a point thirty feet from the upper contact of the Moyie sill. It is a very hard, vitreous, massive, light bluish gray quartzite carrying much feldspar. The whole rock seems to have been recrystallized. The granular-mosaic structure has been largely replaced by poikilitic and micrographic structures. Quartz is thus either regularly intergrown with feldspar or else encloses non-oriented individuals of the same mineral. The feldspar proved to be orthoclase, albite and microperthite, named in the order of their relative abundance. Biotite and sericitic muscovite are, as usual, in considerable amount. A little magnetite and a few minute crystals of anatase are the subordinate minerals. The characters of this contact phase point to the thorough metamorphism and notable feldspathization of the quartzite in the external contact zone of the gabbro.

The main mass of the sill-rock has the composition noted above as found in the sills generally. The grain is here medium to coarse, the structure hypidiomorphic-granular.

At the lower contact the grain of the gabbro is somewhat finer than in the interior of the sill, but the rock is still medium-grained and never compact. At the same time, interstitial and poikilitic quartz, along with biotite, orthoclase and microperthitic feldspar, are increased in amount. There is thus some acidification of the sill at its lower contact, though the rock is still gabbroid in macroscopic appearance and has hornblende and plagioclase (andesine to labradorite) as the chief constituents. Acidification of this order is visible for at least 200 feet from the lower contact. The intrusive rock is yet more abundantly charged with quartz, biotite and alkaline feldspars in the vicinity of the occasional xenoliths torn from the invaded quartzites.

The conditions are different at the upper contact. They may be readily studied on the wagon-road that threads the floor of the western meridional valley, shown in fig. 1. From the upper contact inward for a perpendicular distance of about 150 feet the intrusive is a highly siliceous rock, the mineralogical composition of which is shown in Table I and Table II. The structure of this rock varies irregularly, even in the same slide, from the hypidiomorphic granular of granite to the structure of granophyre or micropegmatite.

TABLE I.

Mineralogical composition of Rocks showing secondary derivation of Granite. (Essential minerals noted in italics.)

I. MOYIE SILL.

Gabbro.	Intermediate rock.	Granophyre-granite.
<i>Hornblende</i>	<i>Hornblende</i>	<i>Biotite</i>
<i>Labradorite</i>	<i>Biotite</i>	<i>Soda orthoclase</i>
Quartz	<i>Andesine</i>	<i>Microperthite</i>
Titanite	Quartz	<i>Micropegmatite</i>
Biotite	Chlorite	Quartz
Apatite	Titanite	Andesine
	Titanif. magnetite	Muscovite
	Apatite	Titanif. magnetite
		Apatite
		Calcite, epidote, kaolin

Country rocks: highly acid mica-bearing quartzite, sometimes slightly feldspathic, containing quartz, biotite and muscovite (sericite) as principal constituents, with orthoclase, epidote, titanite, magnetite, pyrite, zoisite, chlorite, leucoxene and zircon as subordinate minerals. Occasionally a thin layer or parting of more argillaceous composition.

II. PIGEON POINT.

Gabbro.	Intermediate rock.	Granophyre-granite.
<i>Olivine</i>	<i>Hornblende</i>	<i>Anorthoclase</i>
<i>Diallagic augite</i>	<i>Anorthoclase</i>	<i>Oligoclase</i>
<i>Basic labradorite</i>	<i>Plagioclase</i>	Quartz
Apatite	Quartz	<i>Micropegmatite</i>
Titanif. magnetite	Micropegmatite	Chlorite
	Chlorite	Augite (occasional)
	Magnetite	Muscovite
	Apatite	Rutile
	Rutile	Leucoxene
		Hematite
		Apatite

Country rocks: feldspathic quartzite and slate, containing quartz, orthoclase, plagioclase, chlorite, green mica, biotite, magnetite, leucoxene. Feldspar sometimes 75 per cent of the quartzite.

III. SCDBURY DISTRICT.

Norite.	Intermediate rock.	Granophyre-granite.
<i>Hypersthene</i>	<i>Hornblende</i> or	<i>Biotite</i>
<i>Augite</i>	<i>Hypersthene</i>	<i>Orthoclase</i>
<i>Bytownite</i>	<i>Biotite</i>	<i>Micropegmatite</i>
Quartz	<i>Oligoclase-andesine</i>	<i>Microperthite</i>
Biotite	<i>Orthoclase</i>	<i>Microcline</i>
Hornblende	<i>Microperthite</i>	<i>Oligoclase</i>
Apatite	Quartz	Quartz
Magnetite	Epidote	Epidote
Sulphides	Apatite	Ilmenite
	Magnetite	Titanite

Country-rocks: sandstones, graywackes, slates, conglomerates, greenstones, volcanic tuffs and granitoid gneiss.

TABLE II.

Showing the weight percentages of minerals as determined by the Rosiwal method.*

	1.	2.	3.	4.	5.	6.	7.
Hornblende	58.7	54.8	42.9	49.4	---	---	---
Biotite .....	.9	---	6.6	22.0	8.9	22.0	15.2
Labradorite, Ab, An, -Ab, An, }	34.8	25.6	---	---	---	---	---
Andesine, Ab, An,	---	---	18.5	16.5	---	---	---
Oligoclase, Ab, An,	---	---	---	---	1.5	1.5	1.0
Soda-bearing ortho- clase }	---	---	5.5	---	24.9	29.1	32.5
Microperthite	---	---	---	---	---	---	3.9
Quartz	4.0	6.3	22.8	11.7	57.1	46.0	41.6
Muscovite	---	---	---	---	3.2	---	4.6
Apatite .....	.2	---	---	.3	---	.5	.2
Titanite	1.4	2.0	3.7	---	---	---	---
Magnetite	---	.3	---	---	1.9	.5	1.0
Chlorite	---	11.0	---	---	---	---	---
Calcite	---	---	---	---	2.5	.4	---

Total is 100 in each case.

1. Normal unacidified gabbro from sill about eleven miles east of the Moyie sill.

Nos. 2 to 7 inclusive are types from the Moyie sill, specimens taken thus :

2. Thirty feet from lower contact.
3. Two hundred feet from lower contact.
4. Two hundred feet from upper contact.
5. Fifty feet from upper contact.
6. Forty feet from upper contact.
7. Fifteen feet from upper contact.

Table II was constructed by the use of the Rosiwal method for the determination of the relative quantities of the different constituents. The values are only approximate, owing to the difficulties of exact measurement and identification of the mineral grains. No account was taken of the sometimes abundant grains of epidote, occasional grains of calcite (measured in one instance), and often rather abundant scales of kaolin which occur in the slides. These minerals are products of the alteration of the feldspars, that alteration affording another difficulty in using the Rosiwal method for this suite of rocks. The proportions of the micas are probably too high on account of their not being even approximately equidimensional. Though these rocks do not lend themselves to a very satisfactory employment of the method, and though the table cannot be considered as accurate, the strong contrasts between the acid and basic phases of the sill are clearly evident.

* Verh. Wien. Geol. Reichs-Anst., vol. xxxii, 1898, pp. 143 ff.

Since the compositions of the hornblende, biotite and soda-bearing orthoclase are not known, the chemical analyses cannot be calculated from Table II. Direct chemical analyses of types Nos. 1 and 7 in Table II have been made by Professor Dittrich, of Heidelberg, and are recorded in Table III.

TABLE III.

	1.	2.
SiO ₂	51·92%	71·69%
TiO ₂	·83	·59
Al ₂ O ₃	14·13	13·29
Fe ₂ O ₃	2·97	·83
FeO	6·92	4·23
MnO	·14	·09
MgO	8·22	1·28
CaO	11·53	1·66
Na ₂ O	1·38	2·48
K ₂ O	·47	2·37
H ₂ O (below 110° C.)	·10	·14
H ₂ O (above 110° C.)	1·07	1·31
P ₂ O ₅	·04	·07
CO ₂	·06	·13
	<hr/>	<hr/>
	99·78	100·16
Sp. gr.	3·000	2·773

1. Normal unacidified gabbro from sill about eleven miles east of the Moyie sill.
2. Acid rock fifteen feet from upper contact of the Moyie sill.

The rock of col. 2 belongs to the granite family. The silica is normal (higher in types of cols. 5 and 6, Table II), but the total of the alkalis is extraordinarily low, namely 4·85 per cent, or ·76 per cent lower than the total of the potash and soda in the least alkaline among the twenty-six types of granite analyses selected for Rosenbusch's "Elemente der Gesteinslehre." The comparatively high content of lime is probably to be referred to a not unimportant mixture of lime feldspar and alkaline feldspar in isomorphous relation, as well as to a small amount of secondary epidote.

Col. 1 shows the gabbro to be a normal type in some respects, but the high content of silica and relatively low content of alumina and soda are abnormal for gabbro. These features are partly due to the predominance of hornblende over feldspar and to the presence of free quartz. It can be seen by inspection of cols. 1 and 2, Table II, that the gabbro at the bottom of the Moyie sill would give an analysis very close to that of col. 1, Table III, which represents a good type of the

average gabbro from the many sills of the Boundary belt. A comparison of cols. 2, 4 and 7, Table II, shows that col. 4 corresponds to a rock-type intermediate between the two types actually analyzed. It is planned that a rather complete set of total analyses of the various phases of the Moyie sill will be published in the final report of the Chief Commissioner for Canada on Boundary Surveys.

Partially absorbed inclusions of the quartzite occur also in the upper, granitic zone of the intrusive.

Next to the peculiar granite-granophyre is a hundred-foot (thick) zone of intermediate rock which, with rapid transition,

3

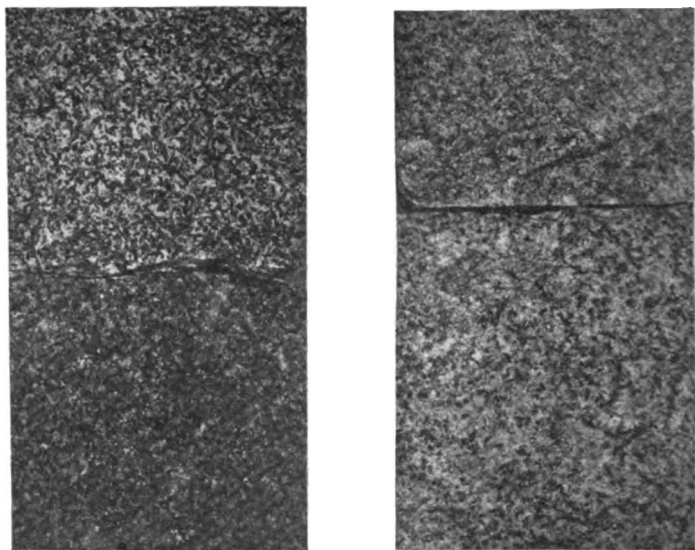


FIG. 3. Photograph of specimens showing contrast of color between a basic and a normal phase of the gabbro of the British Columbia sills and between both of these and two phases of the Moyie Sill granite-granite shown on the left.

replaces the acid rock as the section is thus carried inwards through the sill. The mineralogical composition of this intermediate rock is shown in Tables I and II.

The structure is again hypidiomorphic-granular with continual gradations into the granophyric. The grain varies from medium to rather coarse.

The intermediate rock grades imperceptibly into the normal gabbro of the internal part of the great intrusive body.

The variation in mineral composition among the zones of granite, intermediate rock and gabbro are shown in Table II.

The profound macroscopic differences of aspect are imperfectly illustrated in fig. 3, which shows the variation of color-tint. The corresponding variations in the specific gravity of specimens taken in the cross-section of the sill is shown in the following table:

Locality of specimen.	Sp. gr.
15 feet from upper contact	2.773
40 " " " "	2.784
50 " " " "	2.800
Average for granite zone about	2.790
200 feet from upper contact	3.020
Average for middle of sill about	3.025
200 feet from lower contact	2.967
30 feet " " " "	2.980

A series of determinations showed in addition that the average specific gravity of the normal gabbro in all the sills of the Boundary belt is about 3.020.

Exomorphic contact action was observed at both upper and lower contacts with the Kitchener quartzite. It has taken the form of increasing the already high induration of the sediments with an accompanying special development of biotite at both upper and lower contacts. Though there is evidence of the feldspathization of the quartzite at the upper contact, none has yet been forthcoming for the lower contact, where, nevertheless, feldspar may have been similarly introduced from the magma. Doubtless on account of the chemical nature of the invaded sediments contact metamorphism is not conspicuous in the field, nor is it easy to trace its influence. The writer's impression is that the effects are more manifest, the action having been more intense, at the upper contact than at the lower, but additional field study will be required to test the real truth of that impression.

Apart from the development of exotic feldspar in the quartzite, indications of true pneumatolytic action seem to be lacking at both contacts. Mineral veins, including quartz veins, except occasional stringers of quartz, are conspicuously absent.

Field Hypothesis.—The hypothesis adopted in the field to explain these rocks and their relations involved a secondary origin for the granite-granophyre zone at the top of the sill. That zone was thereby interpreted as due to the contact-action of the gabbro intrusion on the adjacent Kitchener quartzite; digestion and assimilation of the sediments both on the main or "molar" contacts and on the peripheries of blocks shattered off from those contacts, was credited with the formation of a new compound magma from which the highly acid and somewhat anomalous granite was derived. The fact that the acid

rock is practically confined to the upper contact-zone was explained by the collection of the products of digestion at the upper contact by gravitative adjustment in the magma. The low density of the locally formed new magma of assimilation would tend to effect its upward diffusion and the consequent cleansing of the heavier gabbro magma from such acid material. The comparatively slight acidification at the lower contact was attributed to the solution of the quartzite in the period immediately preceding the final consolidation of the sill; at that time the viscosity of the magma was too great to allow of the upward diffusion.

A principal test for such a hypothesis is obvious. If it be true, there should be other examples among the great basic sills cutting siliceous sediments. It has already been noted that there is actually such acidification of the other gabbro sills encountered between Port Hill and Gateway, and that in them the acidification is always most marked at the upper contact. Much more striking examples have been described with unusual thoroughness in Minnesota and Ontario. The comparison of these other cases is so important that the best established types will here be sketched and illustrated in some detail. The further discussion of the Moyie sill will be postponed to later pages, in which a synthetic treatment of all the examples will be undertaken.

B. Occurrences in Minnesota.

(a) The very able and specially detailed memoir of Bayley on the rocks of Pigeon Point contains, doubtless, the most elaborate argument in favor of the secondary origin of some granites. A brief summary of his facts and conclusions may well be given in the works of Bayley's own outline forming the introduction to his paper.

"Pigeon Point is the northeastern extremity of Minnesota. It is one of a series of parallel points extending from Minnesota and Canada eastward into Lake Superior. Its backbone is a great east and west dike-like mass of a gray, coarse-grained rock that has always been called gabbro. This consists of phenocrysts of plagioclase in a diabasic groundmass of the same mineral, olivine and diallage, and consequently, it is a diabase porphyrite. . . .

"The rocks through which the gabbro cuts are evenly bedded slates and indurated sandstones of Animikie age. They dip south-southeast at 15 to 20 degrees, except at a very few places near the contact with other rocks, where they are more or less contorted. . . .

"The most interesting features in the geology of the point relate to the series of rocks usually occurring between the gabbro and the clastic beds. Beginning on the gabbro side the series

comprises in succession coarse-grained red rocks, a fine-grained red rock that is sometimes porphyritic and a well-marked belt of altered quartzites.

"The fine-grained red rock has all the characteristics of an eruptive. It sends dikes into the contiguous bedded rocks, and consists essentially of a hypidiomorphic granular aggregate of plagioclase, anorthoclase and quartz. The quartz and anorthoclase often form micropegmatite, while the plagioclase is in comparatively large grains, some of which have hardly defined idiomorphic outlines. At a few places this red rock is porphyritic, with bipyramidal quartz crystals imbedded in a red granophyric groundmass. The rock is similar to many of the augite-syenites described by Irving as occurring in the Keweenaw series, and is in structure and composition a quartz keratophyre.

"The coarse-grained rocks between the gabbro and the keratophyre are intermediate in character between these two. The variety nearest the gabbro differs but slightly from the basic eruptive. In addition to the gabbro components it contains a little quartz and red feldspar—constituents derived from the keratophyre. As the latter rock is approached, the augite, olivine, and plagioclase disappear, while increased quantities of quartz, red feldspar, and brown hornblende make their appearance, and the rock becomes more and more like the fine-grained red rock. Finally the hornblende disappears and the keratophyre is reached. Since the intermediate rocks occur only between the gabbro and the fine-grained red rock, and since all gradations in composition between the two end members of the series are represented, the coarse-grained red rocks are regarded as contact products formed by the intermingling of the gabbro and the keratophyre magmas."*

After describing the compound external zone of contact metamorphism, Bayley continues:

"From the above-mentioned facts it is concluded that the contact belt represents Animikie slates and quartzites that have been altered near their contact with an intrusive rock. The metamorphism of the quartzites has resulted simply in the recrystallization of the quartz and feldspar of the fragmental grains, with the addition, perhaps, of a little orthoclase.

"Since, in several instances, the gabbro is in direct contact with the metamorphosed rocks, while the keratophyre is not to be found in the neighborhood, it is inferred that the former rock and not the latter was the cause of the contact action."

The significant paragraph follows:

"Inclusions of fragmentals in the gabbro and the keratophyre have alike suffered the same alterations as have taken place in the various members of the contact belt, with this difference, that quartzite inclusions in the basic rock are often surrounded by a

* W. S. Bayley, Bull. 109, U. S. Geol. Survey, 1893, p. 11.

rim of red rock, identical in all its properties with the keratophyre. This suggests that the keratophyre itself may be of contact origin."

Finally:

"The conclusion reached is that, in all probability, the keratophyre is of contact origin—that is, it was produced by the

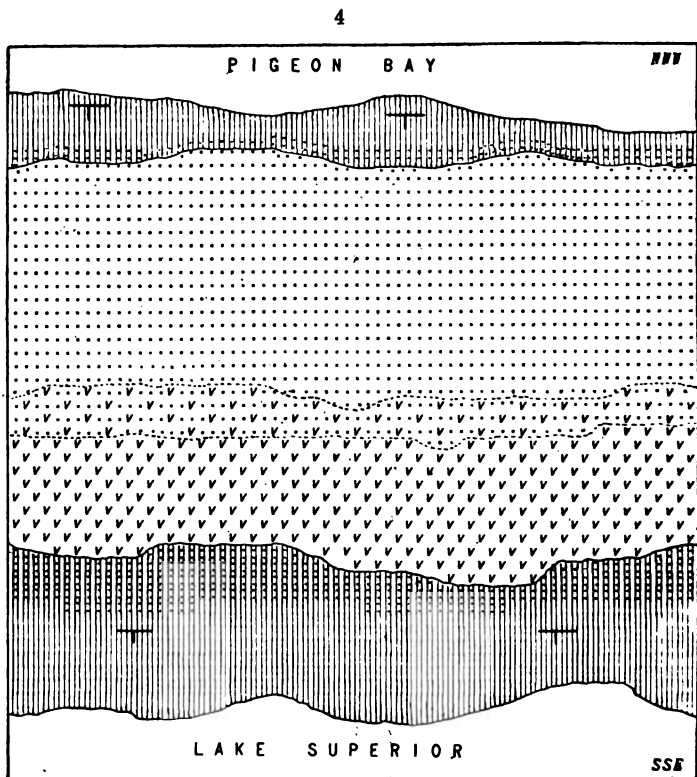


FIG. 4. Diagrammatic map of part of Pigeon Point, Minnesota, showing general relations among the different rock formations; after Bayley.

1. Animikie quartzites and slates. 2. Contact zone in the Animikie sedimentaries. 3. Olivine gabbro. 4. Intermediate rock. 5. Soda granite and keratophyre. Conventional sign for strike and dip. Scale: nine inches = one mile.

fusion of the slates and quartzites of the Animikie through the action upon them of the 'gabbro.' The magma thus formed then acted in all respects like an intrusive magma. It penetrated the surrounding rocks in the form of dikes, and solidified as a soda-granite under certain circumstances, and under others as a quartz-keratophyre."*

*Op. cit., p. 12.

The diagrammatic map of fig. 4 generalizes the field relations as expressed in Bayley's maps. There have been omitted from the diagram certain complexities in the maps showing the actual geology. The essential features are thus made all the more evident; at the same time it is believed that this arbitrary treatment of the maps does not introduce error in principles.

A summary of the mineralogical compositions of the gabbro, intermediate rock, granite-keratophyre (granophyre) and invaded sediments is given in Table I. The correlative differences in chemical constitution are noted in Table IV.

TABLE IV.

Selected Analyses, Bayley on Pigeon Pt.

	A.	B.	C.	D.	E.	F.
SiO ₂	49·88%	57·98	72·42	73·85	59·71	70·31
TiO ₂	1·19	1·75	·40	·05	tr.	tr.
Al ₂ O ₃	18·55	13·58	13·04	10·91	18·32	12·81
Fe ₂ O ₃	2·06	3·11	·68	6·98	8·11	7·26
FeO	8·37	8·68	2·49	·89	·85	·88
MnO	·09	·13	·09	.....	.....	.....
CaO	9·72	2·01	·66	·44	1·05	·60
BaO	·02	·04	·15	.....	.....	.....
MgO	5·77	2·87	·58	1·52	3·54	2·03
K ₂ O	·68	3·44	4·97	1·39	3·43	1·90
Na ₂ O	2·59	3·56	3·44	2·28	1·93	2·19
H ₂ O	1·04	2·47	1·21	1·88	3·24	2·22
P ₂ O ₅	·16	·29	·20	.....	.....	.....
	100·12	99·91	100·33	100·19	100·18	100·20
Sp. gr. ...	2·923— 2·970	circa 2·740	2·620	not given, prob. ca 2·70	not given, prob. ca 2·75	

- A. Olivine diabase ; aver. of five specimens . . p. 37
- B. Intermediate rock 63
- C. Red granite ; aver. of 7 specimens 56
- D. Unaltered quartzites ; aver. comp. 90
- E. Unaltered slate 90
- F. Approximation to aver. comp. of sediments 113

The general similarity in the character and spatial arrangement of the rocks at Pigeon Point and on the Moyie River is apparent. The comparison of conditions is obscure only as relates to the structural cross-section. The Moyie intrusive is unquestionably a sill. The underground relations of the Pigeon Point intrusive, for lack of decisive field evidence, have not been fixed beyond the possibility of doubt. Bayley says :

"The most prominent features of these gabbro masses are those of dikes. As has already been mentioned, the larger one [the one referred to in the present paper] in many places presents perpendicular walls both to the north and to the south. It occupies all the highest portions of the point, and these are in a straight line. It has the appearance of an intrusive mass, and is like any one of those forming the numerous points to the north of the international boundary line. It has been regarded as a dike by both Irving and N. H. Winchell. Its contact with the sedimentary rocks is only occasionally to be seen. At several of these contacts the eruptive has the appearance of having escaped from between the dike walls and thrust itself for a short distance between the fragmental beds, or having piled itself up around the dike orifice and overlapped the intruded rocks. . . . At only two places on the north shore do the fragmental rocks appear, and at these places they are far below where they should be were they interbedded with the gabbro, and in neither case is the contact like that of interbedded eruptive and sedimentary rocks."

He concludes that :

"The larger mass of the Pigeon Point gabbro is in the form of a dike, which has broken through its walls at certain places and intruded itself between the strata of the surrounding rocks."*

In accordance with his view Bayley's cross-sections show vertical contacts among all the igneous rock members and also between sediments and eruptives.

On the other hand, Professor N. H. Winchell states, in a personal letter to the writer :

"All my observations bearing on the relations of the gabbro to the Animikie on Pigeon Point lead to the conclusion that the gabbro is later than the Animikie. But the term gabbro here is made to include those coarse non-ophitic dikes that resemble gabbro and which are also allied to diabase. There are abundant places where this rock is in the form of sills in the Animikie. The great backbone of Pigeon Point, which is the most distinctly gabbroid of the intrusive rocks, is simply a large example of a sill, while, as I interpret the structure, many of the dikes cutting the Animikie are only contemporary offshoots from it."

With Winchell's view there agrees the observation of Bayley that the feldspar phenocrysts of the porphyritic gabbro are sometimes "arranged in rude layers parallel to the dip surfaces of the quartzite. Their longer axes are usually in the direction of the dip of the sedimentary rocks."† This orientation suggests flow-structure parallel to contacts. Professor Bayley has, by letter, restated to the writer his conclusion that "the gabbro was intruded as a boss or huge dike, certainly not

* Op. cit., pp. 22-23.

† Op. cit., p. 23.

as a sill," but adds the remark that "while the contacts of the quartzites with the red rock and gabbro so far as they were seen are vertical, it does not necessarily follow that they are vertical with depth." He continues: "I have no means of knowing the date of the intrusion. With respect to the tilting (of the quartzites) my guess is that the intrusion was prior to the latest tilting, but later than an earlier tilting lakeward."

The possibility that the Pigeon Point eruptive is either a true sill only locally breaking across the bedding of the sediments or at any rate dips as a whole to the south-southeastward, is further suggested by the analogy of the many undoubted sills of gabbro cutting the southerly to southeasterly dipping Animikie of Minnesota. Some of these sills have likewise zones of soda granite lying between the gabbro and the sediments on the southerly flank of the gabbro. Thus in those cases the sediments dip under the gabbro on the one side of the eruptive body and away from the granite on the other side.

Bayley's full and trenchant argument for the contact origin of the soda granite and granophyre need not be repeated. The independent origin of the acid rock is rendered highly improbable by the occurrences of the intermediate rock lying directly between the gabbro and the sediments without the intervention of the true granite or granophyre.

The efficiency of contact-shattering in aiding the digestion of the slates and quartzites is strikingly manifest in Bayley's descriptions.

"Very close to the red rock appears a belt in which the various rocks are in the most complicated relations imaginable. In the eastern portion of the point this belt is well seen on the southern shore, about one-third of a mile from the end of the point. (See Pl. XVI.) Here the red rock is exposed in low cliffs, and in it are small, sharp slate and quartzite inclusions, into which the red rock penetrates in every direction. The exact line of contact between the red rock and the bedded fragmentals cannot be detected, as they appear to merge gradually into one another, the latter becoming redder and redder as they approach the former, which penetrates them in veins and dikes, and finally includes numerous pieces in such a way as to yield a good eruptive breccia."

"Some of the inclusions are very sharp and but little altered, while others are partially dissolved, and are surrounded by concentric zones, resulting from the action of the red rock upon the material of the inclusion, and the reciprocal effect of the partially dissolved inclusion upon that portion of the red-rock magma immediately contiguous to it. . . . Thus it would seem to be a fact beyond controversy that the red rock is the immediate cause of the alteration noticed in the fragmental rocks and of the brec-

cia observed along its contact with them. If, however, the contact belt is examined very closely, it is found that although the red rock is always accompanied by a zone of this belt, there are localities in which the latter occurs without the presence of the former. . . . The metamorphosing rock seems to be the gabbro. Just as in the case of the contacts with the red rock, the quartzites become mottled as they approach the eruptive, and inclusions of the former in the latter are so frequent that there appears to be a gradual transition between the two rocks.”*

Similar shatter-breccias are described at the northern contact. The metamorphism of the inclusions is there the same in kind as on the southern contact but is less intense.†

(b) A significant discovery was made at a mining prospect on Governor's Island just south of Pigeon Point. The shaft started in hardened slate at the surface, then struck red quartzite and finally red granite where the sinking was discontinued. In this case there is no question that the sediments overlie the granite in a relation similar to that involved in the sill theory of the Pigeon Point intrusive.‡

(c) Parallels to the Pigeon Point case have also been found on Spar, Jarvis and Victoria Islands.§ Lawson has described other examples among the Logan sills of Lake Superior, and says that the sills are repeated by step-faults gently tilting the sills to the southeast at the maximum angle of five degrees.¶

(d) Grant describes the great gabbro area of Cook County, Minnesota, as a laccolith in the gently dipping Animikie quartzites, slates and graywackes. He maps soda granites passing into alkaline quartz porphyries on the southern flank of the gabbro or in it. This latter occurrence is possibly to be related to the occasional horizontal dips of the Animikie.¶

N. H. Winchell maps a broad band of the red granite to the southward of the huge gabbro mass of Lake County. He states that the southern limit of the gabbro forms the northern limit of the red granite, but that there are numerous places where these rocks are intricately interbedded and in some instances isolated areas of the red rock are surrounded by gabbro.** The official atlas of the Minnesota Geological Survey indicates still other large-scale examples of the same or similar close relations of gabbro and red granite—notably those mapped in vol. vi, plates 68, 69, 84, 85 and 87.

* Op. cit., pp. 28-29.

† Op. cit., p. 81.

‡ Final Report, Geol. Surv. of Minnesota, vol. iv, 1899, p. 516, and vol. v, 900, p. 799.

§ Bayley, op. cit., p. 30; cf. E. D. Ingall, Ann. Rep. Geol. Surv. Canada, 1888, Pt. H, pp. 45 and 49.

¶ Bull. 8, Geol. Surv. Minnesota, 1893, pp. 30-33-42-44.

¶ Final Rep. Minn. Geol. Surv., vol. iv, 1899, pp. 323 and 326.

** Ibid., pp. 296-7.

C. The Sudbury Intrusive Sheet.

A still more remarkable parallel to the conditions of the Moyie sill has been rather fully described by Barlow and Coleman, following the earlier work of Walker in their respective memoirs on the geology of the Sudbury District, Ontario. In the scale of the various related phenomena, in the wonderfully systematic arrangement of the different rock-formations, and in the occurrence of valuable ore-bodies directly and geneti-

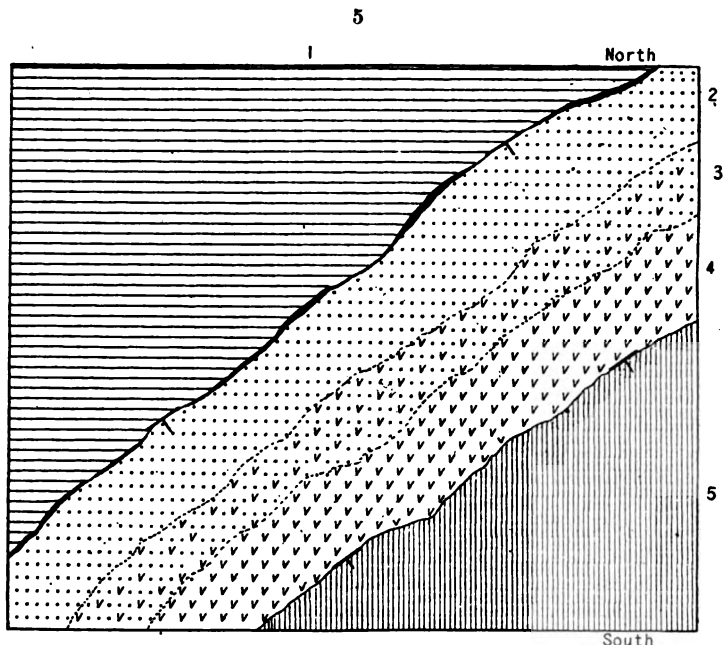


FIG. 5. Diagrammatic map of part of the Northern Nickel Range, Sudbury District, Ontario; after Coleman.

1. Granitoid gneiss, greenstones and graywackes. 2. Norite. 3. Intermediate rock, transitional between norite and micropegmatite. 4. Micropegmatite. 5. Slates, sandstones and volcanic tuffs. (The position of the sulphide ores shown by heavy black line.) Conventional sign for strike and dip. Scale: one inch = two miles.

cally associated with the intrusive, the Sudbury District example stands unique in petrographical records.

The latest reports of Barlow and Coleman agree in the conclusion that the famous nickel-bearing eruptive has the form of an enormous intrusive sill of a composition exactly analogous to that of the Moyie sill excepting as regards the development of the valuable sulphides. It is "a vast sheet of eruptive rock having a basin shape; a sheet nearly 40 miles long

and 17 miles wide, and probably a mile and half to two miles thick on the average, if the (average centripetal) dip (of the sheet) is 45 degrees."*

This great sheet cuts sediments and schists referred to the Laurentian and Upper Huronian. Their general field relations are summarized in the diagrammatic map of fig. 5. drawn from a part of Coleman's official map of the "Northern Nickel Range." Again the gabbroid rock (norite) is seen to be concentrated on the lower contact of the sheet, the acid rock, micropegmatite or granophyre, graduating into true granite, on its upper contact, while between the two is a zone of intermediate rock. On the "Southern Nickel Range" across the spoon-shaped basin, Barlow has determined the same arrangement of acid, intermediate and basic zones in the sheet, which there, however, agreeably with the basin theory of structure, has a northerly dip; so that in this case, the norite occurs on the south side of the sheet, the granite-granophyre zone on its northern side. On the basin theory of the structure, the volume of the granite-granophyre in this sheet is to be measured by hundreds of cubic miles.

All around the basin the nickel ores form a more or less continuous zone at the lower contact of the norite. The sulphides are also to be found in especial abundance as segregations in apophysal offshoots of the norite where the basic magma penetrated fissures outside the lower contact of the sheet.

Coleman states that where the band of eruptive (outcrop edge of the sheet) is narrow, there is less change in the rock in passing from the lower to the upper contact, the most basic norite as well as ore being absent for the most part. He also notes the absence of granophyre or granite in the smaller intrusions of the norite which occasionally appear outside the main basin.†

Eruptive breccias due to the shattering of the invaded formations by the hot magma are found at both upper and lower contacts.‡

Coleman notes that in the northern nickel range the contact metamorphism is more intense next the upper acid zone than next the norite. He explains this as possibly due to the fact that the rocks at the lower contact were already well crystallized before the intrusion took place, while the sediments along the upper contact were then capable of notable minera-

* A. P. Coleman, Rep. Bureau of Mines, Ontario, 1903, p. 277. Cf. A. E. Barlow, Ann. Rep. Geol. Surv. Canada, vol. xiv, 1904, p. 72; also stereogram accompanying Coleman's report.

† 1904 report, p. 212, and 1903 report, p. 286.

‡ A. E. Barlow, op. cit., pp. 122, 129 and plates; A. P. Coleman, Rep. Bureau of Mines, Ontario, 1904, p. 213; T. L. Walker, Quart. Jour. Geol. Soc., vol. liii, 1897, p. 54.

logical changes. The metamorphism on the upper contact extends outward for a distance of from 1000 to 1500 feet.

There seems to be a decided lack of pneumatolytic action (other than that due to water vapor) incident to the intrusion.*

Coleman has concluded that the intrusion of the sheets antedated the synclinal warping of the region to which the present basin shape of the sheet is attributed.†

The mineralogical compositions of the norite, intermediate rock and micropegmatite-granite are summarized in Table I. Their chemical compositions are entered in Table V, taken from Walker's paper, page 56. The corresponding specific gravities also show the significant homologies existing between these rocks and those of Pigeon Point and of the Moyie sill. The value of a close study of these tables will appear in the following general comparison of the rocks and of their relations to one another.

TABLE V.

	1.	2.	3.	4.	5.
SiO ₂	49.90%	51.52%	64.85%	69.27%	67.76%
TiO ₂	1.47	1.39	----	.78	.46
Al ₂ O ₃	16.32	19.77	11.44	12.56	14.00
Fe ₂ O ₃	----	.47	2.94	2.89	----
FeO.....	13.54	6.77	6.02	4.51	5.18
MgO.....	6.22	6.49	1.60	.91	1.00
CaO.....	6.58	8.16	3.49	1.44	4.28
Na ₂ O.....	1.82	2.66	3.92	3.12	5.22
K ₂ O.....	2.25	.70	3.02	3.05	1.19
H ₂ O.....	.76	1.68	.78	.76	1.01
P ₂ O ₅.....	.17	.10	.24	.06	.19
	99.03	99.71	98.30	99.35	100.29
Sp. gr.....	3.026	2.832	2.788	2.724	2.709

1 to 5—"Specimens range from north to south" across the Sudbury intrusive sheet, that is, from near lower contact (No. 1) to near upper contact (No. 5).

Synthetic Discussion.

Magmatic Assimilation.—The secondary origin of granite has long been maintained by N. H. Winchell, who has referred to the Pigeon Point case as, among others, demonstrating the fact.‡ Bayley came to the same belief for the granite and granophyre of the point, but did not extend his argument in detail to cover other occurrences among the Minnesota intrusives. On the other hand, the principle has not been accepted

* A. E. Barlow, op. cit., p. 129.

† 1903 report, p. 277.

‡ Final Rep. Minn. Geol. Surv., vol. v, 1900, p. 62, etc.

as applying to these localities even by Van Hise, whose rare knowledge of Lake Superior geology must give his opinion exceptional weight.* Even the latest text-books of geology give most inadequate treatment of the doctrine though it refers to one of the most important problems in the whole field of geology. Doubtless the majority of petrologists are to-day unfavorable to the assimilation theory of granite and its relatives except as it applies to a very limited, in point of volume insignificant, modification of certain magmas at their contacts.

Van Hise's chief argument against the contact origin of the Pigeon Point granite emphasizes the fact that that rock has not the chemical composition either of the sedimentary formation or (as especially shown in the surplus of alkalies and the deficiency of iron in the granophyre-granite) of a direct mixture of gabbro and sediments.† The much quoted argument of Brögger with reference to the Norwegian granites is based on a similar fact.‡ Many other writers have, on a similar ground, excluded contact assimilation as playing any considerable part in the formation of abyssal or hypabyssal magmas.

In practically every case the opponents of the assimilation theory have treated of the assimilation as essentially a static phenomenon. Each interpretation of field facts has been phrased in terms of magmatic differentiation *versus* magmatic assimilation as explaining the eruptive rocks actually seen on the contacts discussed. Nothing seems more probable, however, than that such rocks are often to be referred to the compound process of assimilation accompanied and followed by magmatic differentiation. The chemical composition of an intrusive rock at a contact of magmatic assimilation is thus not simply the direct product of digestion. It is the net result of rearrangements brought about in the compound magma of assimilation. In the magma, intrusion currents, convection currents and the currents set up by the sinking or rising of xenoliths must take a part in destroying any simple relation between the chemical constitutions of the intrusive and invaded formations. Still more effective may be the laws of differentiation in a magma made heterogeneous by the absorption of foreign material which is itself generally heterogeneous. The formation of eutectic compounds or mixtures, the development of density stratification, and other causes for the chemical and physical resorting of materials in the new magma ought certainly to be regarded as of powerful effect in the same sense.

A second fundamental principle has as a rule been disregarded in the discussions on magmatic assimilation. The *form*

* Monograph XLVII, U. S. Geol. Surv., 1904, pp. 730-733.

† Op. cit., p. 733.

‡ Die Eruptivgesteine des Kristianiagebietes, Pt. II, 1895, p. 130.

of the intrusive body, and the relation of the accessible points of its contacts to that form as a whole, must be taken into account. If, for example, differentiation of the compound magma has taken place so as to produce within the magma chamber layers of magma of different density, the lightest at the top, the heaviest at the bottom, the actual chemical composition of the resulting rock at any contact will depend directly on the magmatic stratum rather than on the composition of the adjacent country-rocks.

Thirdly, the method of intrusion is of primary significance in the discussion of assimilation in a given instance. There are strong reasons for believing that the subterranean chambers of stocks and batholiths have been opened largely or at least in part through magmatic "stopping," whereby magmas have made their way upward through the invaded formations by engulfing suite after suite of blocks shattered off from those formations by the heat of the intrusives.* In such a case the destructive action at the molar contact is chiefly physical, and chemical solution is subordinate. Most of the solution takes place in the complete digestion of the sunken blocks and is therefore abyssal rather than marginal. The conditions are peculiarly favorable for the systematic differentiation of the new compound magma. The chemical composition of the intrusive at any contact will thus depend on the constitution of a (possibly well differentiated) magma containing materials won from *all* the invaded formations and not simply materials won from the immediately adjacent country-rock. Brögger's argument derived from the low content of lime in the Christiania granite cutting thick limestones (themselves overlying an enormous thickness of crystalline schists, etc.) is clearly inconclusive until it can be shown that this and the other two factors just noted have not been at work.†

Magmatic stopping has, in all probability, taken place to some extent in the great intrusive body at Pigeon Point. The specific gravity of the gabbro varies from 2.923 to 2.970. Molten at 1400 degrees Cent., its specific gravity, at atmospheric pressure, would be not far from 2.43 to 2.48. The specific gravities of the intermediate rock and granite are respectively 2.740 and 2.620; molten at 1400 degrees Cent., they would, at atmospheric pressure, be about 2.30 and 2.19 respectively. The specific gravity of the invaded sediment varies from 2.70 to about 2.75. Blocks of the quartzite and slate immersed in any of the molten magmas and there assuming the temperature of 1400 degrees Cent., would at the same

* Cf. R. A. Daly, *The Mechanics of Igneous Intrusion*, this Journal, vol. xv, 1903, p. 269, and vol. xvi, 1903, p. 107.

† Cf. Loewinson-Lessing, *op. cit.*, p. 368.

pressure have specific gravities varying between 2.60 and 2.65. There are good reasons for believing that plutonic pressures would not essentially affect these contrasts of density. Assuming a certain degree of fluidity in the magma (an assumption underlying the whole of this paper and believed to be demonstrated by such facts as the patent ease of diffusion that once reigned in each of the intrusives), it appears that blocks of the sedimentary rocks must sink in the magma, whether acid or basic.*

The actual shatter-breccias described by Bayley are therefore to be attributed to the last destructive effort of the magma, which, at that time, through cooling, had become too viscous to allow of the sinking of the xenoliths.

A precisely similar argument applies to the Moyie and Sudbury examples (see table of specific gravities and table in this Journal, vol. xv, 1903, p. 277). All these igneous bodies, though not intruded by magmatic stoping, yet show that process to have assisted in the production of the granites and granophyres. Whether this process has there been more or less efficacious than molar or marginal assimilation, perhaps cannot be determined.

In all these cases the stoping that did occur must clearly have tended to destroy a simple chemical identity between igneous rock and country-rock at any given contact.

Summary.—It will be useful to review the chief field and laboratory observations so far noted as favoring the assimilation theory when applied to the granites and granophyres described in this paper.

1. Bayley's elaborate argument is believed to be valid except as it fails to take differentiation into account. No fact has been noted either by the writer in connection with the Moyie sill or in the descriptions of the other examples which tends to weaken that argument.

2. Belief in the truth of his conclusion is greatly strengthened by the repeated occurrence of essentially the same phenomena in widely separated regions.

- a.* At Pigeon Point, at Sudbury and on the Moyie River there occur intrusive bodies of gabbro passing by gradual transitions (as shown by chemical, mineralogical and specific gravity determinations) into the border phases of granite and granophyre. Both types of rock clearly belong to the same period of intrusion.

- b.* All three igneous bodies are of relatively great thickness, which means that, other things being equal, they possessed relatively great stores of thermal energy.

* Cf. R. A. Daly, *op. cit.*, 1903, p. 277, etc.

c. In each occurrence the gabbro contains xenoliths of the more acid sedimentary rocks. These blocks are commonly more or less digested and the product of this local solution is always closely allied to, if not equivalent to, the granophyre-granite phase.

d. In each case there is correspondence though not equivalence between the composition of the acid border-phase and the average composition of the invaded formation. This important fact is emphasized in Tables I, II, III, IV and V, in which the silica and alkalies are either directly or inferentially seen to be more or less abundant in the granophyre-granite according to the relative abundance of those oxides in the respective country-rocks.

e. A considerable number of other examples not as yet thoroughly studied have been noted in British Columbia and Minnesota. The conditions are throughout identical or so allied as to favor one explanation common to all the occurrences.

f. The assimilation theory is also supported by certain other facts which have already been mentioned but merit a more detailed discussion such as is attempted in the sequel.

3. The principal objection to the doctrine of assimilation, namely, the objection that chemical analyses disprove any genetic relationship between intrusive and invaded formation at certain accessible contacts, cannot hold, because that objection allows no place for differentiation in the magma made compound by assimilation.

Asymmetry of the Intrusive Bodies.—There remains for particular explanation the cardinal fact that all the intrusive bodies are asymmetric. The granophyre-granite is always concentrated on one side of the intrusive, that is, along the upper contact or the side away from which the enclosing sediments dip.

In all the localities the dips of the sedimentaries and of the intrusive sheets are believed to have been flatter at the time of the injection of the magma than those dips now are. It is, indeed, possible that, in every instance, the gabbro sheet lay practically horizontal during the period of cooling and consolidation. In any case the granophyre-granites appears to have always overlain their respective gabbroid associates.

Three possible explanations have offered themselves for this asymmetry. (a) It is conceivable that extensive assimilation occurred only on the upper contacts; or (b) the asymmetry may be due to the density stratification of magma compounded of gabbro and digested sediments; or (c) due to a combination of both those factors.

One or more subordinate suppositions are necessary if the assimilation be credited essentially to the upper contact. On

the one hand, the invaded formations above and below the gabbro might be lithologically so different that the one above was much more subject to contact alteration than the one below. This idea is at once declared irrelevant in the British Columbia and Minnesota cases, where there is certainly no evidence of differences of digestibility.

On the other hand, it is possible that the original gabbro was differently constituted, and thus more energetic in assimilation, along the upper contact than elsewhere. Magmatic water or other strong solvents may thus be conceived to have early concentrated in the upper zone of each sill. In favor of this view would seem at first sight the fact that at Pigeon Point the zone of external metamorphism is reported by Bayley to be much wider on the upper contact than on the lower. (See fig. 4.) The same seems to be true in the Sudbury case, but is explained by Coleman as noted on a previous page. The writer could find no absolutely certain evidence of such differential metamorphism about the Moyie sill, yet considers it as probable.

That the conditions for the complete assimilation of the invaded formations obtained throughout the intrusive bodies is illustrated in the unmistakable digestion of xenoliths found at all depths in the gabbro. As already pointed out, the assimilation here belongs to the period immediately preceding the consolidation of the gabbro. A much greater volume of similar material derived from the interaction of gabbro and sedimentary rock must have been formed from other blocks in the hotter, more fluid, and more energetic magma of the preceding period. There seems to be no possible doubt that most of that material has diffused upward and now forms part of the granophyre-granite zone.

The simplest and most probable cause for that diffusion is, as suggested in the field hypothesis for the Moyie sill, the difference of density between the acid magma of assimilation and the enclosing gabbro.

It is quite possible that the metamorphosing effect of the new magma may have been greater than that of the original pure gabbro. The new magma would presumably carry with it the water derived from the digested sediments which, apparently in every case, are notably more hydrous than the original gabbro magma. The accompanying table shows the proportion of water (or loss on ignition) found in the analyses of the rocks of Pigeon Point.

Rock.	Per cent of water.
Gabbro	1.04
Intermediate rock	2.47
Red soda granite	1.21
Slate	3.24
Quartzite (loss on ignition)	1.88

So far as such water determinations in the crystallized rock can be considered as indicating a true condition of the magma before solidification, the table implies that the compound magma corresponding to the "intermediate rock" still held the extra water of assimilation up to the moment of crystallization; and, secondly, that the well differentiated magma corresponding to the soda granite had lost about half of the water of assimilation before final solidification. It is, accordingly, quite possible that this extra water which the upper acid zone could not hold in permanent combination, has been responsible for the unusual amount of external metamorphism in the sediments south of the Pigeon Point intrusive. Similar reasoning may apply to the Sudbury example, but the required elaborate chemical study of its more complex terranes has not yet been made.

In favor of this hypothesis is the fact that, so far as known to the writer, differential contact metamorphism of the kind here in discussion has never been described in connection with a sill that does not also show evidence of strong internal assimilation.

Finally, there is no cause yet well determined why water or other solvents should be systematically concentrated from the original magma along the roof of an intrusive sill. Such concentration may, indeed, be the rule, but it has apparently not been announced by any worker among the thousands of basic sills described in geological literature.

The conclusion seems justified that the special intensity of the metamorphism on the upper contact of certain intrusive bodies is probably not due to the special activity of solvents in the original magma along that contact. The explanation seems to lie partly in the different liability of the roof-rocks and floor-rocks to metamorphic change, but yet more in the metamorphic effects of water vapor set free in the digestion of the invaded hydrous sediments. This water vapor may have also assisted in the solvent work of the magma at the main upper contact, and, finally, in increasing the fluidity of that magma.

Magmatic Differentiation.—The development of basic, intermediate and acid zones in each of the sills is, thus, believed to have been the result of the density stratification of the compound magma of assimilation. The efficiency of differential density in separating out lighter acid material from the heavier basic, has been ably discussed and affirmed by Loewinson-Lessing.* It is unnecessary to recapitulate his argument, with which the present writer is in full accord.

* Op. cit., pp. 344-354.

Loewinson-Lessing points out that when large amounts of foreign rock-material is digested in a magma, there is established a special tendency toward a systematic differentiation of the mixture.* Liquefaction will then take place when the cooling mixture reaches a certain temperature. The same author also holds that, according to the principles of physical chemistry, a magma becomes actually more fluid as a result of digesting foreign material. Differentiation is thereby facilitated. Vogt's valuable researches tend to corroborate this view.†

The granites and granophyres of the Moyie sill, of the Pigeon Point intrusive, and of the Sudbury sheet are to be regarded as not directly or merely due to the contact solution of sedimentary rocks and schists by gabbro; they are controlled in their final composition by a common process of differentiation supplementary to the gravitative effect. At Pigeon Point the acid rock, whatever its structure and grain, is a rather definite mixture of oxides. This is illustrated in the analyses of granular soda granite, the "quartz keratophyre", and the porphyry of Little Brick Island near Pigeon Point.‡ For lack of sufficient analyses the same statement cannot be made concerning the Moyie sill, but within limits it applies to the huge Sudbury sheet.§

The acid zone may have won some of its soda from the original magma; the gabbro may now hold some of the potash with the silica derived from the micaceous and feldspathic quartzites and other sediments. It is obvious, however, that all the details of the chemical processes engaged in this type of magmatic separation (chemical affinity in magma disturbed by gravitative diffusion currents) cannot be worked out from existing data on the magmatic behavior of silicates.

The intermediate rock at all three localities may be regarded as occupying zones of incomplete differentiation.

Special interest attaches to the occurrence of the nickel ores along the lower contact of the Sudbury sheet. Barlow, Coleman, Vogt and Walker agree that these sulphides are soluble in magmas. The solubility is in inverse proportion to the acidity of those magmas.|| The fact suggests that the sulphides have been precipitated from the norite which has been acidified by assimilation. The concentration of the ore on the lower contact is again the result of differentiation through contrasts of density, the sulphides settling to the bottom of the sheet. Loewinson-Lessing has already suggested this gen-

* Op. cit., pp. 375 ff.

† Op. cit., Part 2.

‡ Bull. 228, U. S. Geol. Surv., p. 89.

§ See A. P. Coleman, 1904 report, p. 218.

|| J. H. L. Vogt, op. cit., p. 229.

eral hypothesis to explain the segregation of sulphide-ores, without, however, connecting the concentration with gravitative influence. Coleman has announced the view that the ores have thus settled to the bottom of the sill, but has not connected the action with the digestion of acid rock in the norite.* The whole array of facts connected with the Sudbury intrusive is so accordant with the double theory of assimilation and differentiation through density stratification, as to single out this particular case as perhaps, of all those noted in the present paper, the most convincing and illuminating.

It is necessary that brief reference be made to an alternative view of all these related phenomena. One may conceive that the granite-granophyre, intermediate rock and gabbroid rock in each of the intrusive sheets may be explained by simple differentiation from an *original* magma through density stratification but without the aid of significant assimilation of the country-rocks. Lack of space forbids that this hypothesis be here discussed at length. The writer believes that the hypothesis is untenable or, at least, is much less adapted to explaining the facts than the hypothesis of assimilation accompanied and followed by differentiation. Most of the facts on which that belief is founded have been already implied or expressly noted.

Among the significant facts are the following:

1. There is a close similarity in composition between the granite-granophyre zone and rims of manifest digestion about xenoliths now surrounded by gabbro. This consanguinity is inexplicable on the theory of mere differentiation within the original magma.

2. The genetic relationship between the granite-granophyre zone and the invaded sediments is further shown by certain special features already described among the structures of the acid rock in the Moyie sill, and of the overlying, metamorphosed quartzite. For example, the development of remarkably poikilitic quartz in the granite-granophyre and in the recrystallized quartzite (the quartz of the latter being largely or wholly indigenous) may be mentioned. This repeated occurrence of a peculiar structure finds no simple explanation on the pure-differentiation theory.

3. In the period of high temperature preceding the viscous period when the visible xenoliths were frozen in the gabbro, thousands or millions of other xenoliths were completely or in part digested in the gabbro magma. The product of their digestion can be found, apparently, in no other place than in the existing acid zone of each intrusive sheet.

* 1903 report, p. 277.

4. Mere differentiation of an original magma (through density stratification) cannot readily explain the slight but certain excess of silica along the lower contact of the Moyie sill. That degree of acidification is readily understood on the assimilation theory.

5. Along the British Columbia boundary a large number of contemporaneous gabbro sills of practically identical mineralogical and chemical composition have been found. In most of these no true granite-granophyre zone occurs. The composition of these gabbros is essentially equivalent to that of the gabbro in the central part of the Moyie sill; yet, on the pure-differentiation theory we should expect a distinct difference of composition between these other sills and the basic pole of differentiation in the Moyie sill. The assimilation-differentiation theory finds no difficulty in the essential equivalence of composition.

6. The assimilation-differentiation theory demands that a great absolute amount of thermal energy be credited to a sill in which secondary granite has been formed; that sill must always be thick. Other things being equal, granite formed by mere differentiation from an original magma should be found also in sills of less thickness, though here again the absolute thickness must be considerable. True granite with the relations described in this paper has never been found as a continuous zone in any intrusive sheet 500 feet or less in thickness. On the pure-differentiation theory it is difficult to understand why differentiation should afford true granite in a sheet of the strength observed at Pigeon Point, and should not afford a true granite zone in a sheet 400 or 500 feet thick. The assimilation-differentiation theory readily interprets the fact as due to the relatively enormous amount of heat required for the generation of the granite-granophyre zone, namely, an amount of heat characteristic only of thick intrusive sheets.

7. The pure-differentiation theory has to face another difficult question which does not arise if the assimilation-differentiation theory be accepted. Why was differentiation in the original magma postponed to the moment of intrusion? This difficulty is, of course, by no means conclusive against the pure-differentiation theory, but it means one more unavoidable theoretical burden weighting the pure-differentiation theory in a way which renders, by contrast, the assimilation-differentiation theory one of relative simplicity and, by so much, of greater strength.

General Application.—In the foregoing discussion the secondary origin of some granites has been deduced from the study of intrusive sills or sheets; but it is evidently by no means necessary that the igneous rock body should have the

sill form. The wider and more important question is immediately at hand—does the assimilation-differentiation theory apply to truly abyssal contacts? Do the granites of stocks and batholiths sometimes originate in a manner similar or analogous to that just outlined for the sills?

The writer has briefly noted general reasons affording affirmative answers to these questions.*

Gabbro and granophyre are often characteristically associated at various localities in the British Islands as in other parts of the world.† The field relations are there not so simple as in the case of the Moyie sill, for example, but otherwise the recurrence of many common features among all these rock-associations suggests the possibility of extending the assimilation-differentiation theory to all the granophyres. Harker's excellent memoir on the gabbro and granophyre of the Carrock Fell District, England, shows remarkable parallels between his "laccolite" rocks and those of Minnesota and Ontario.‡

At Carrock Fell there is again a commonly occurring transition from the granophyre to true granite, and again the granophyre is a peripheral phase. Still larger bodies of gabbro, digesting acid sediments yet more energetically than in the intrusive sheets, and at still greater depth, would yield a thoroughly granular acid rock as the product of that absorption with the consequent differentiation. This does not imply, of course, that all granites are of this origin, but it is quite possible that most intrusive granites are either of this origin or have been more or less modified through assimilation.

The difficulty of discussing these questions is largely owing to the absence of accessible lower contacts in the average granite body. All the more valuable must be the information derived from intrusive sills. The comparative rarity of such rock-relations as are described in this paper does not at all indicate the exceptional nature of the petrogenic events signalized in the Moyie, Pigeon Point or Sudbury intrusives. It is manifest that extensive assimilation and differentiation can only take place in sills when the sills are thick, well buried, and originally of high temperature. All these conditions apply to each case cited in the present paper. The phenomena described are relatively rare largely because *thick* basic sills cutting acid sediments are comparatively rare.

On the other hand, there are good reasons for believing that a subcrustal gabbroid magma, actually or potentially fluid, is general all around the earth; and secondly, that the overlying solid rocks are, on the average, crystalline schists and sediments

* This Journal, vol. xv, 1903, p. 269, vol. xvi. 1903, p. 107.

† See A. Geikie, *Ancient Volcanoes of Great Britain*, 1897.

‡ *Quart. Journal Geol. Soc.*, vol. 1, 1894, p. 311 and vol. li, 1895, p. 125.

more acid than gabbro. Through local, though widespread and profound, assimilation of those acid terranes by the gabbro, accompanied and followed by differentiation, the batholithic granites may in large part have been derived.* True batholiths of gabbro are rare, perhaps because batholithic intrusion is always dependent on assimilation.

The argument necessarily extends still farther. It is not logical to restrict the assimilation-differentiation theory to the granites. The preparation of the magmas from which syenites and diorites, for example, have crystallized, may have been similarly affected by the local assimilation of special rock-formations. The development of some of the anorthosites of the Canadian and Adirondack Archean was possibly conditioned on the digestion of part of the associated crystalline limestones by plutonic magma.

The officers of the Minnesota Geological Survey have shown that the same magma represented in the soda granite and granophyre of Pigeon Point forms both dikes and amygdaloidal surface flows.† The assimilation-differentiation theory is evidently as applicable to lavas as to intrusive bodies. But demonstration of the truth or error of the theory will doubtless be found in the study of intrusive igneous bodies rather than in the study of volcanoes either ancient or modern.

Finally, the fact of "consanguinity" among the igneous rocks of a petrographical province may be due as much to assimilation as to differentiation.

* Cf. R. A. Daly, *op. cit.*

† N. H. Winchell, *Final Rep. Minn. Geol. Surv.*, vol. 4, 1899, pp. 519-22.

ART. XXIV.—*On Tychite, a New Mineral from Borax Lake, California, and on its Artificial Production and its Relations to Northupite*; by S. L. PENFIELD and G. S. JAMIESON.

Historical.—The new mineral to be described in this paper was discovered by the merest chance in 1895, when some minerals from Borax Lake, San Bernardino County, California, were being studied by one of the present writers (Penfield). At the time mentioned, word had been received from Mr. Warren M. Foote of Philadelphia that he had some unknown minerals from the Borax Lake region, and arrangement was made for their examination in the mineralogical laboratory of the Sheffield Scientific School. One of the minerals, which proved to be a new species, consisted of octahedral crystals, averaging about 3^{mm} in diameter, and concerning it Mr. Foote wrote that it was a carbonate of magnesium and sodium containing chlorine. The material sent for examination consisted of a large number of the octahedral crystals, and from amongst them a small one, which was perfect in form and seemed to be in every way typical of the lot, was selected for the purpose of making a few preliminary tests. It was brought in contact with a drop of nitric acid on a watch glass and dissolved with effervescence; the solution gave the flame test for sodium, a minute drop of it gave the reaction for magnesium with ammonia and sodium phosphate, but a test for chlorine with silver nitrate gave a negative result. Thinking over what else might possibly be present, the idea of a sulphate suggested itself, and a test with barium chloride indicated the presence of the SO_4 radical. Accordingly, a letter was sent to Mr. Foote informing him that there evidently was some mistake, for the mineral he had sent proved to be a sulphate and not a chloride. This elicited an immediate reply from Mr. Foote, stating that, on the contrary, the mistake was on our part, for he had always obtained the test for chlorine and had repeated the experiment with like results; thereupon the test was repeated by us, and the presence of chlorine was found in one crystal after another. The fact, therefore, was established, that in the material sent there were two minerals crystallizing in octahedrons, one containing the sulphate radical, the other chlorine, and that by chance a crystal of the rarer sulphate happened to be the one first selected for making the initial examination. A preliminary notice of the chlorine compound was published by Mr. Foote,* who named the mineral *northupite* after Mr. C. H. Northup of San Jose, California,

* This Journal (3), 1, p. 490, 1895.

who first observed the new mineral and supplied the material for investigation. A complete study of the chemical composition and physical properties of the new compound was subsequently made by Pratt, who found the composition to be $\text{MgCO}_3, \text{Na}_2\text{CO}_3, \text{NaCl}$, his results being published in this Journal.*

Being assured of the existence of a second, new, octahedral mineral, associated with the northupite, Mr. Foote generously responded to our request to send to New Haven his entire stock of crystals in order that a search might be made for the missing sulphate. The following simple method of testing was employed, which did not in any way injure the specimens: Some dilute nitric acid containing a little silver nitrate was prepared, and with a broom-straw a minute drop of the liquid was applied to each crystal. Thus, if chlorine was present, a little silver chloride would be formed and the drop of liquid would become milky-white. In testing several hundred crystals in this way, only two were found which did not give the reaction for chlorine. One of these was a small but perfect octahedron, the other a small cluster of octahedrons, of somewhat inferior quality: together they weighed only about 0.10 gram. It was hoped, however, that by sacrificing the specimens for chemical analysis sufficient determinations could be obtained for deriving the formula; but in this we were disappointed, for, unfortunately, the analysis met with an accident before a single determination had been made. We were thus compelled to abandon the hope of determining the composition of the new mineral until other crystals should be found in new lots of the northupite.

Recently our attention was called to the unknown sulphate by observing in the stock of Mr. Lazard Cahn of New York a supply of northupite crystals which he generously loaned to us for examination, but when tested they all proved to be the chlorine compound. Likewise Mr. Warren M. Foote of Philadelphia has been kind enough to send us his entire stock of northupite, consisting of something over four thousand crystals, among which we had the good fortune of finding one small octahedron, weighing but 0.0109 gram. Curiously enough, this was among the last ten crystals which were tested, and was found after hope of obtaining the desired sulphate had practically been given up.

Artificial production.—Believing that the unknown sulphate would prove to be closely related to northupite, and knowing that de Schulten† had succeeded in making the latter artificially, it occurred to us that possibly the wished for sulphate

* This Journal (4), ii, p. 133, 1896; also, iii, p. 75, 1897.

† Bull. Soc. Franc. de Min., vol. xix, p. 164, 1896.

might also be prepared synthetically. Following in general the method of de Schulten, 8 grams of Na_2CO_3 and 34 grams of Na_2SO_4 were dissolved in 120^{cc} of water, and to the solution 1.4 grams of MgSO_4 were added, which immediately produced an amorphoid precipitate, presumably of some basic magnesium carbonate. The mixture, contained in a flask, loosely stoppered to prevent evaporation, was then heated on a steam bath. By using chlorides in the place of sulphates, as described above, de Schulten succeeded in making northupite in a crystallized condition in about seven hours; in our experiment, however, we waited five days, the solution being heated without interruption, before any signs of crystallization appeared. In the meantime we had tried heating a similar mixture in a sealed tube at a high temperature, without definite results, and had practically given up hope of obtaining the desired crystals. It was almost a matter of accident, therefore, that the flask containing the mixture was left standing on the steam bath for so long a time. When the crystallization had once started, however, it apparently proceeded quite rapidly, and the insoluble material in the flask was almost wholly converted into octahedral crystals, very symmetrical in development and remarkably uniform in size, about 0.15^{mm} in diameter. Having once produced a crop of crystals, we are now able, by "seeding" or adding some of the product already formed to a new experiment, to produce crystals in fifteen hours, though it still seems to take several days to complete the reaction. When examined under the microscope, it was found that each crystal contained minute inclusions, presumably of basic magnesium carbonate, but the inclusions constituted a very small proportion of the total bulk of the material. The crystals were next suspended in acetylene tetrabromide, diluted with benzol, and it was found that they all floated when the specific gravity was 2.594, and on diluting to 2.583 almost all of the material sank. The mean of the two values, 2.588, may therefore be taken as the specific gravity of the mineral. It was found that the lighter crystals, left floating on the heavy solution, were preceptibly richer in inclusions than those which sank at 2.583. The crystals are quite hard and give a gritty sensation when ground in an agate mortar. They scratch calcite and probably, like northupite, have a hardness between 3.5 and 4. The crystals are isotropic when examined in polarized light. Using two surfaces which come together at the apex of an octahedron as a prism, it was possible to determine approximately the index of refraction, but the surfaces of the crystal were not good enough to make the determination accurate beyond the second place of decimals: the value found was 1.510, while n_v for northupite was 1.514.

An analysis of the purest material, separated by means of the heavy solution, gives the formula $2\text{MgCO}_3 \cdot 2\text{Na}_2\text{CO}_3 \cdot \text{Na}_2\text{SO}_4$, the results being as follows :

	I.	II.	Theory.
SO ₃	15·08	15·06	15·33
CO ₂	33·55	33·45	33·72
MgO.....	15·83	15·77	15·33
Na ₂ O.....	35·49	35·65	35·62
	<hr/> 99·95	<hr/> 99·93	<hr/> 100·00

The slight discrepancies between the results of the analyses and the theory are probably to be accounted for by the presence in all of the crystals of the minute inclusions mentioned on the previous page.

The finely powdered salt does not dissolve to any extent in hot water, nor does it suffer decomposition. Some powder, boiled with water for a considerable time, then filtered and dried, gave the following results:—SO₃, found 15·21 per cent, theory 15·33 per cent. The filtrate gave only a slight reaction of a sulphate when tested with barium chloride.

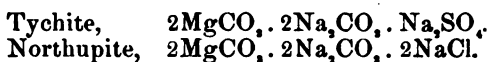
Name.—We have named the new and rare sulphate *tychite*, from τυχη, meaning luck or chance, a name which it well deserves, when it is considered that out of fully five thousand specimens examined, the very first crystal and one of the ten last crystals tested proved to be the sulphate, and only two other specimens were found, the ones lost in an unsuccessful attempt to make an analysis.

Comparison of the artificial salt with the natural mineral.—Without question, the artificial salt is identical with the mineral found at Borax Lake: they both contain the same constituents. They crystallize not only in the same system, but also in octahedrons. They are isotropic, although the last crystal of tychite found showed some slight action on polarized light, which seemed to be confined only to the exterior portions of the crystal, for fragments from the interior were wholly isotropic. The specific gravity of the artificial salt is 2·588, of the crystal examined by Pratt (the analysis of which was lost) 2·456, and of the last crystal found by us 2·30. The last crystal, however, contains numerous inclusions, which undoubtedly account for its low specific gravity. As far as can be recollected, the crystal examined by Pratt was very white and pure, but not equal in transparency to the artificial crystals. Both Pratt's determination, 2·456, and ours of the artificial salt, 2·588, are somewhat higher than the specific gravity of northupite, as might be expected from differences in composition: Pratt found the specific gravity of northupite to be

2380, and de Schulten determined that of the artificial salt as 2377. By using two of the faces which meet at the apex of the octahedron as a prism, we have succeeded in determining the index of refraction of the last crystal found. The surfaces of the octahedron were not very perfect, and had to be covered over for the most part, taking the reflections of the signal from only the tip end of the crystal, and the refraction of light through the same. The value obtained, $n_v = 1.508$, compares favorably with that of the artificial salt, 1.510, especially when it is taken into consideration that the condition did not favor exact determinations in either case. A further argument for the identity of tychite and the artificial salt, if any is needed, is that at Borax Lake both tychite and northupite occur together, and were formed undoubtedly under similar conditions, while in the laboratory either of these closely related chemical compounds may be made by only varying the conditions of the experiment by using sodium sulphate for the one and sodium chloride for the other.

Of the four specimens of tychite thus far found, three have been very symmetrically developed octahedrons, but small, measuring not over 3^{mm} in diameter, and noticeably whiter than the average of the northupites. It is the small size of the crystals which favored the discovery of the new mineral, for in the original preliminary test one of the smallest and whitest specimens was selected, both because of its evident purity, and also with the idea of not using up any more material than was necessary. Those who may happen to have northupite crystals and wish to search for specimens of the new mineral, may look for tychite therefore among the smaller crystals. We are informed in a recent letter from Mr. Northup that the chances of finding additional crystals of tychite, or of the associated minerals, northupite and pirssonite, are too remote to be seriously considered, as the old borax works are now dismantled. Tychite, therefore, promises to be a very rare mineral, unless a new locality for it happens to be discovered. The single crystal which we recently had the good fortune to find, Mr. Foote has generously presented to the Brush Collection of the Sheffield Scientific School, and both for this gift and for the interest he has taken in assisting us in our investigation we take pleasure in expressing our most sincere thanks.

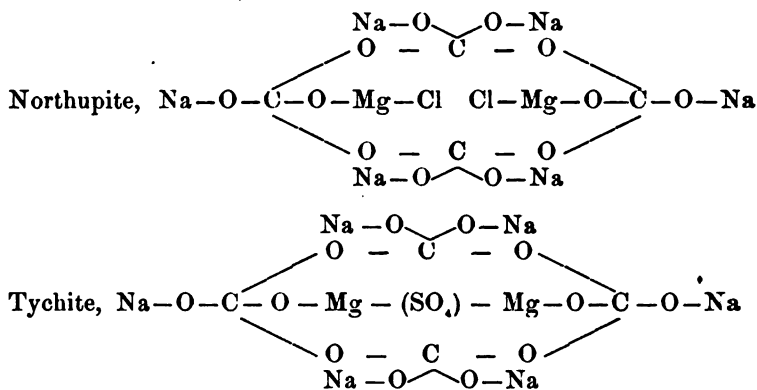
Comparison of tychite and northupite.—The two minerals, found so intimately associated with one another and both crystallizing in octahedrons, are chemically closely related, but in order to show the relation it is necessary to double the formula of northupite, as determined by Pratt. The compositions may then be expressed as follows :



Other physical properties are given below:

	Specific gravity.	Index of refraction, n_p .
Tychite,	2.456 natural.	1.508 natural.
	2.588 artificial.	1.510 artificial.
Northupite,	2.380 natural.	1.514 natural.
	2.377 artificial.	

Theoretical.—There seems to be far more interest connected with the present investigation than the mere description of a new species. Although northupite is somewhat slowly soluble in cold water, and is quickly decomposed by boiling water with the separation of magnesium carbonate, tychite is almost insoluble, even when its fine powder is treated with boiling water. Unlike most insoluble substances, however, which precipitate quickly as soon as the constituents necessary for their formation are brought together, northupite and tychite are formed slowly. In de Schulten's experiment, northupite was obtained after seven hours heating, and in ours it took nearly as many days of continued heating to obtain crystals of tychite. It would seem as though the slowness with which these substances are formed might be taken as an indication of their having a complex molecular structure, and that the element of time is necessary for the arrangement of the atoms in a state of equilibrium. Just what the arrangement of the atoms is, we are not able to determine, but the simplest and most symmetrically developed formulas which suggest themselves are the following:



In these formulas the four carbon atoms are united by oxygen in ring formation, which it may be assumed it takes some time to establish, but, when once established, accounts

for the stability of the compounds. It is possible also that the assumed symmetrical arrangement of the atoms in the molecule is the cause of the crystallization of these compounds in the isometric system, for, as a rule, salts of a highly complex nature crystallize in some system other than the isometric. Moreover, if the above formulas are correct, it might be expected that tychite would be more difficultly soluble in water than northupite, for the SO_4 radical uniting the two magnesium atoms would serve, as we might say, to protect the latter from attack, while the sodium atoms could not be taken away without disturbing the equilibrium of the molecule. Perhaps also the union of the magnesium atoms by the SO_4 radical in tychite is more difficult to establish than the combination of the two chlorine atoms with magnesium in northupite, which may account for the greater length of time required to make the sulphate compound artificially.

In these compounds, two chlorine atoms in the one and a SO_4 radical in the other play the same rôle, and are isomorphous with one another in the broader sense of the term, namely, that different constituents may enter into similarly constituted molecules without changing the crystalline form. In simple chemical compounds, it is contrary to all experience that a chloride and a sulphate should have the same crystalline form, or be isomorphous with one another. In the salts under consideration, however, it is assumed that some definite arrangement of the large number of sodium, oxygen, carbon and magnesium atoms, by virtue of *mass effect*,* determines the crystalline form of the compounds, and that the rôles played by two chlorine atoms in the one and a SO_4 radical in the other are relatively so unimportant that either of these constituents may enter into the molecule without changing the crystalline form. Whether it is possible to obtain a single crystal containing both the two chlorine atoms and the sulphate radical replacing one another as isomorphous constituents, or to obtain a single crystal with a nucleus of one salt and an external growth, in parallel position, of the other, we are not as yet able to state, but experiments along these lines, to determine to what extent the principles of isomorphism may be applied to so widely different radicals as Cl , and SO_4 , under the influence of mass effect action, will be carried on and form the subject of a later communication. In one experiment, in which the attempt was being made to obtain a product containing both Cl , and the SO_4 radical, a small crop of octahedral crystals was formed which reacted for neither chlorine nor sulphate. In appearance

* Compare *mass effect* action as applied to tourmaline (Penfield and Foote, this Journal (4), vii, pp. 122-124); also to the alunite-jarosite group of minerals (Hillebrand and Penfield, this Journal (4), xiv, pp. 216-220).

the crystals were in every respect like those of the artificial northupite and tychite. As seen with the microscope the crystals were full of inclusions, and, in forming, had evidently enclosed an unusually large amount of amorphous magnesium carbonate precipitate. We assumed at once, and correctly, that the compound would prove to be like northupite and tychite, except in having a CO_2 radical in the place of Cl , and SO_4 , namely, $2\text{MgCO}_3 \cdot 2\text{Na}_2\text{CO}_3 \cdot \text{Na}_2\text{CO}_3$; see page 222. The analysis, made on a small quantity of the rather impure product, gave almost the theoretical percentage of CO_2 , but the MgO was high and the Na_2O low, which was to be expected. Attempts will be made later to produce this salt in a state of purity, when it will be described more minutely.

Mineralogical Laboratory of the
Sheffield Scientific School of Yale University,
New Haven, Conn., July, 1905.

ART. XXV.—*A Modification of Victor Meyer's Apparatus for the Determination of Vapor-Densities*; by B. J. HARRINGTON.

THE ingenious apparatus devised by the late Professor Victor Meyer for the determination of vapor-densities has been in use for many years and has proved of great value for the purpose for which it was intended. It, however, has certain imperfections, being awkward on account of its height and very liable to be broken, especially in the hands of inexperienced workers. Two modified forms of the apparatus have been devised by the writer and have proved so useful in our own laboratories that it has been deemed worth while to publish a description of them. In both cases an attempt was made to simplify the apparatus and make it more convenient and rapid to work with.

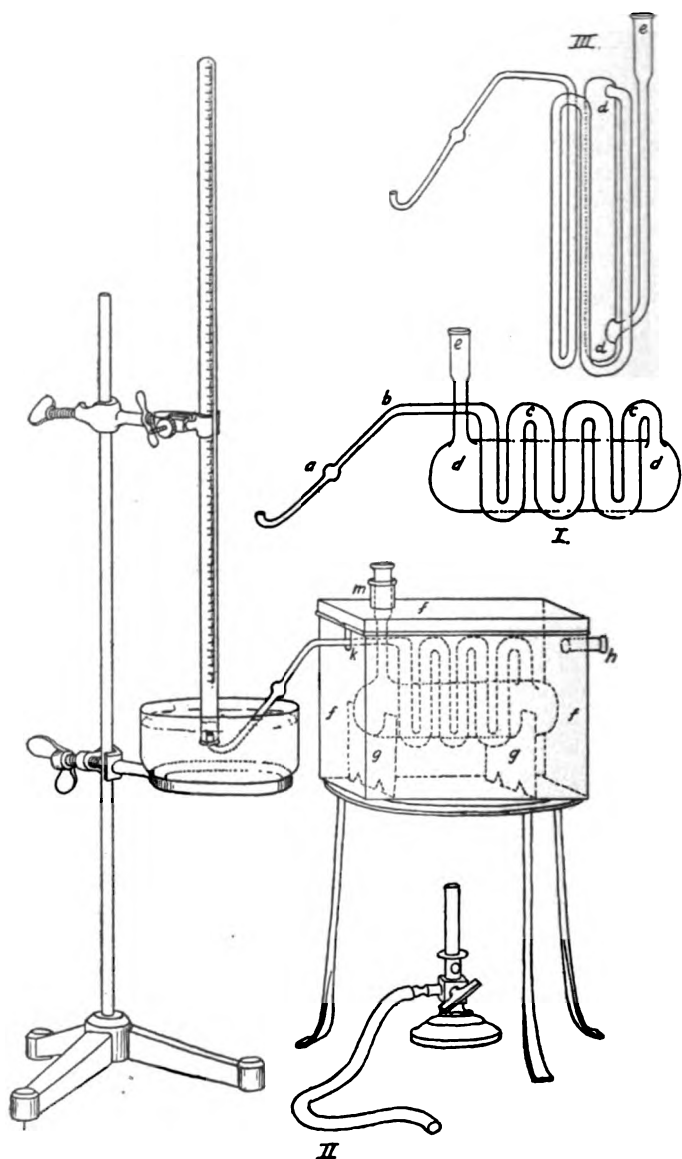
The first form tried is that shown as fig. I in the accompanying illustration. It will be observed that the receptacle *dd* is horizontal instead of vertical and that the long stem of Meyer's apparatus is bent upon itself a number of times; the apparatus accordingly occupying but little space. Instead of the long outer tube or jacket ordinarily employed, a box made of tinned iron or copper is used.

In making an actual determination the space around the glass at *m* and *k* (fig. II) is packed with a little asbestos, and it has been found advantageous to lay a piece of asbestos card on the cover of the box.

The weighed material in the ordinary stoppered tube or bulb is dropped in at *e* (fig. I) and as it has not far to fall there is no need of the usual cushion of asbestos or sand. As soon as one operation is completed the vapour is quickly swept out of the apparatus by connecting the tube *ab* (fig. I) with the vacuum-pump, the water in the box *ff* (fig. II) being kept continuously boiling. In this way one operation quickly succeeds another, and it has been found that students can make two or three determinations in the time required for one with the ordinary apparatus.

The second form experimented with is shown at III. In this the receptacle *dd* of I is placed vertically, as it was thought that the vapor would be less likely to be carried into the delivery tube than if the horizontal position were adopted. The tube *e* is somewhat longer than in the first form (I) but the curve at the bottom checks the velocity of the little tube containing the liquid and no asbestos is required at the bottom

of *dd*. Like No. I, this form is much more easily dried out than the ordinary apparatus. The metal box for No. III. is



not shown in the drawing, but its construction can be readily understood. With both forms of apparatus *e* was closed with

an ordinary cork, a correction being made for the small quantity of air displaced by the cork, but of course one of the improved appliances for introducing the liquid could be employed. So far the apparatus has been tried only for bodies with comparatively low boiling points, but it could no doubt be adapted for use with liquids with higher boiling points.

The following table gives a series of molecular weight determinations kindly made for me by Mr. Douglas McIntosh, D.Sc., of this university, with the different forms of apparatus, and gives an idea of the results which may be expected. Apparatus No. II. has, on the whole, been found to give more concordant results than No. I, but the latter is simpler and less likely to be broken than the former and in either case the figures obtained are sufficiently accurate for the purpose. They were obtained by working very rapidly and with no special precautions, and cannot therefore be fairly compared with those given by Victor Meyer's apparatus in the last column; for in the case of the latter Dr. McIntosh states that he took every precaution in order to ensure the most accurate results possible.

MOLECULAR WEIGHT DETERMINATIONS MADE BY MR. DOUGLAS
McINTOSH, D.Sc. (Air = 2×14.44)

	Modified Apparatus No. I.	Modified Apparatus No. II.	Meyer's Apparatus.
Methyl	35.0		
Alcohol	36.0		
CH ₃ OH	36.9	32.9	
(32)	36.5	33.4	
	34.0	33.5	31.91
	36.9	33.1	31.94
	34.7		
	34.8		
	37.2		
	Mean 35.8	Mean 33.2	Mean 31.93
Methyl	46.0		
Alcohol	43.1	44.1	
C ₂ H ₅ OH	45.0	44.7	46.70
(46)	44.5	44.3	46.10
	43.6		
	42.3		
	Mean 44.1	Mean 44.4	Mean 46.40

228 *Harrington—Modification of Victor Meyer's Apparatus.*

	Modified Apparatus No. I.	Modified Apparatus No. II.	Meyer's Apparatus.
Acetone	59.4		
$\text{CH}_3 > \text{CO}$	57.2		
CH_3	59.2	58.9	
(58)	58.0	59.0	57.90
	59.0	58.5	57.80
	59.1		
	<hr/>	<hr/>	<hr/>
Mean	58.6	Mean 58.8	Mean 57.85
Ether	76.1		
$(\text{C}_2\text{H}_5)_2\text{O}$	80.0		
(74)	82.6	77.7	
	74.9	75.0	75.70
	82.6	77.1	76.90
	76.1	76.2	
	<hr/>	<hr/>	<hr/>
Mean	78.7	Mean 76.5	Mean 76.30
Benzol	77.3		
(C_6H_6)	73.3	81.2	
(78)	80.2	80.8	79.00
	81.1	80.4	79.20
	81.7	79.7	
	<hr/>	<hr/>	<hr/>
Mean	78.7	Mean 80.5	Mean 79.10
Chloroform	134.9		
CHCl_3	131.5		
(119.5)	122.6		
	126.3	124.2	
	136.8	124.9	
	125.5	122.8	123.20
	125.8	126.2	123.00
	<hr/>	<hr/>	<hr/>
Mean	129.1	Mean 124.5	Mean 123.10

McGill University, May, 1905.

ART. XXVI.—*A New Lower Tertiary Fauna from Chappaquiddick Island, Martha's Vineyard* ;* by THOMAS C. BROWN. (With Plate VIII.)

CHAPPAQUIDDICK Island lies at the eastern end of Martha's Vineyard and owing to the shifting nature of the sands and varying tidal currents, it is at times connected with that island, but it is for the greater part of the time completely separated from it. Dr. Arthur Hollick has made a very careful study of the structure of this island and collections of the molluscs and plants found fossil upon it. The fossil plants have been very fully described by him in the Bulletin of the New York Botanical Garden, vol. ii, No. 7. The mollusc material has not been described and its horizon was provisionally set as Cretacic by Dr. Hollick because of the similar lithological character of this material with other deposits on Martha's Vineyard containing undoubted Cretacic fossils.

A careful study of the fossils has shown that this material is not Cretacic but Eocene in age and that it contains a new and peculiar fauna, a fauna which differs considerably from that of the Eocene deposits of the southern Atlantic slope.

In describing the deposits from which these molluscan remains were obtained Dr. Hollick says: ". . . the Island may be said to be composed of reassorted drift. . . . These hills in general may be described as kame-like, both in appearance and in composition. They are rounded accumulations of sand, gravel and cobble stones, with some bowlders, and were evidently formed by water action. In many places the sand and gravel is cemented together by limonite, forming hard lenses and strata, and ferruginous concretions and shaly fragments are abundantly represented."†

In his geological studies of Martha's Vineyard and surrounding islands Professor Shaler recognizes these ferruginous concretions and concerning them he says: "On the Island of Chappaquiddick and in the region near Edgartown, occasional fragments of a ferruginous sandstone are found which closely resemble in their general character the materials containing the Cretaceous fossils, but as they offer no organic remains I hesitate to consider them of that age."‡

Dr. Hollick considered these concretions as lithologically identical with those containing Cretacic molluscs and plants and set out to make a collection of organic remains that would

* The investigations on which this paper is based were carried on in the Paleontological Laboratory of Columbia University and the types of these species are in the university collection.

† Bull. N. Y. Botanical Garden, vol. ii, No. 7, p. 399.

‡ N. S. Shaler, 7th Ann. Report U. S. G. S., p. 326.

substantiate the point. "A systematic exploration of all exposures was therefore prosecuted; hundreds of the concretions and shaly fragments were broken open and critically examined and the result was a collection, not only of molluscs but also of plant remains, a few of which were found sufficiently well preserved for identification."*

Upon his return Dr. Hollick submitted the molluscs to Professor R. P. Whitfield of the American Museum of Natural History for a hasty examination, and concerning them Professor Whitfield spoke thus: "I have examined the fossils you sent the other day but I cannot satisfy myself as to their age. They consist of a *Modiola*, which apparently does not differ from our common *M. plicatula*, of the harbor here; an *Anomia* which might pass for *A. gigantaria* of the lower greensand marls of New Jersey, if it were not for the *Modiola*; also a single imperfect internal cast of a small (young?) *Pectunculus* not enough of it to tell the species, and a small bivalve of which I cannot yet determine the genus. These are the only shells I can recognize, and from their evidence I should think the rocks could hardly prove to be Cretaceous."†

These fossils were also submitted to Professor Grabau of Columbia University for examination. "Mr. Grabau is of the opinion that they may represent a new fauna, of more recent age than the Cretaceous, and this is quite consistent with the conditions under which they occur, so far to the south of any recognized Cretaceous outcrop. The character of the matrix also, with a single exception, is notably different from that in which undoubted Cretaceous molluscs have been found elsewhere, being a micaceous sandstone instead of a hardened clay or greensand."‡

A careful study and detailed comparison of these fossils with descriptions, figures, and specimens of the Cretacic and Eocene species shows that these fossils represent a new fauna of Eocene age. This fauna, however, differs widely from that of the Eocene deposits of the South Atlantic coast and seems to be more closely allied in general to the Eocene of England. Some of the specimens are very well preserved, while others are only represented by external and internal molds. Many of these molds are of such a nature and so well preserved that a wax impression can easily be taken and the characters of the fossil observed and compared. The following descriptions and comparisons include the best preserved and most typical specimens. Some of these are not perfect enough to be described as new species, but most of them can be generically placed.

* Bull. New York Botanical Garden, vol. ii, No. 7, pp. 399-400.

† Bull. N. Y. Botanical Garden, vol. ii, No. 7, p. 400.

‡ Ibid., p. 401.

Modiola vineyardensis sp. n. Pl. I, fig. 1.

Shell strongly ventricose, with a very prominent, almost angular umbonal ridge extending from the beak to the ventral margin. Shell distinctly concave anterior to this ridge; posterior to this ridge it becomes flattened toward the posterior margin; anterior end extremely short barely extending beyond the beak; posterior margin angulate, front margin nearly straight only a slight emargination occurring, basal end rounded; the portion of the margin from the end of the hinge line to near the point of angulation, and from beyond the point of angulation to the ventral margin, are almost straight lines. Surface with pronounced raised radii, flattened at the top and separated by spaces equal to or slightly wider than the radii; the radii are very fine and crowded on the anterior portion of the shell, much coarser on the median and posterior region, and distinct from the beak to the margin. They increase in size progressively from the dorsal to the ventral portion of the shell, with a corresponding increase in the width of the interspaces. They increase in number by intercalation as well as bifurcation. Fine distinct growth lines cross and cancellate the radii.

This species resembles *M. alabamensis* Aldrich,* from the Eocene of Maryland, but differs from it in general outline. It has a less curved anterior border and more radii, which are very distinct from the margin to the beak. The shell is shorter antero-posteriorly, and the posterior margin is more obtusely angulate. The shell of *M. vineyardensis* is also more ventricose and the umbonal ridge more angular and more pronounced.

In general outline this species approaches more nearly *M. grammatus* Dall,† from the Oligocene of Florida. The surface ornamentation is very similar, but judging from Dall's figure his shell is less ventricose and the umbonal ridge less angular and less distinct.

But even closer than to any of these is the resemblance of this species to *M. elegans* Sowerby‡ from the Eocene of England as figured and described by Wood among the Eocene bivalves. In general outline and surface ornamentation the resemblance is very close. *M. elegans* is, however, slightly less angulate at the postero-dorsal margin and judging from the figures is less ventricose.

Compared with the modern *M. plicatula* Lamarck, living along the Atlantic coast, *M. vineyardensis* seems to be nar-

* Bull. of Am. Palaeont., vol. i, p. 68, pl. v, fig. 18.

† Trans. Wagner Free Institute of Sci., vol. iii, pt. 4, p. 794, pl. xxx, fig. 2.

‡ Paleontological Soc. Monographs, London 1861-71. Eocene Bivalves, p. 65, pl. xii, fig. 5 (c).

rower toward the ventral portion of the shell, while the postero-ventral margin is more nearly a straight line and the radii are more numerous and finer and proportionately more widely separated. In *M. vineyardensis* and *M. plicatula* the mode of increase in the number of the radii by occasional intercalation and bifurcation is very similar. In *M. plicatula* the umbonal ridge is less angulate and less pronounced.

The shell described is a left valve with the following measurements: length 32.5^{mm}, width 14^{mm}. Several small specimens of this same species occur in other fragments of the concretions, as well as imprints of these shells. These smaller specimens correspond exactly with the growth lines of the younger stages in the larger individuals.

Modiola vineyardensis mut. *inornata*.

This mutation is very similar to the type of the species described above, except that the radii are very faintly marked. Fine, distinct, concentric growth lines mark the surface. Distinct radii can be seen on the anterior and umbonal region of the shell. These radii are flattened on top and separated by very narrow impressed lines. They fade out as they pass away from the umbonal and completely disappear on the ventral portion of the shell.

This mutation is represented in the collection by a comparatively small left valve.

Modiola Hollicki sp. n. Pl. VIII, fig. 2.

Shell ventricose, with a prominent umbonal ridge extending from the beak to the ventral margin; shell sloping abruptly to the anterior margin and becoming flat in the postero-dorsal part; anterior end rather short; anterior end rounded, front margin slightly arcuate, ventral margin broadly arcuate, rounded, postero-dorsal margin obtusely angulate; cardinal line straight; surface without ornamentation except for rather faint concentric lines of growth.

In general outline this species somewhat resembles *M. Mitchelli* Morris,* from the Eocene of England. It has a more obtuse postero-dorsal angle and is slightly narrower, with a slightly arcuate anterior margin instead of being emarginate as in that form.

Represented in the collection by two specimens, one nearly perfect left valve (fig. 2) and a valve lacking the beak and hinge area. These occur together with the *Corbulas* (see below) in a fine-grained hard ferruginous lute concretion quite different in character from the micaceous sandstone concretions in which all the other fossils are found.

* Palaeontological Society Monographs (see above), p. 68, pl. xiii, fig. 10.

Corbula Whitfieldi sp. n. Pl. VIII, fig. 3.

Shell large for the genus, ventricose and subtriangular; beak high and incurved; anterior margin sharply rounded, ventral margin broadly arcuate in the median and anterior portions but sinuously emarginate posteriorly; the posterior end of the shell is narrow, produced and abruptly truncated. Surface marked by distinct concentric asymmetrical folds or concentric wrinkles which are broadly rounded on top, with the dorsal border slightly broader and not as abruptly sloping as the ventral border. The folds are separated by narrow channeled interspaces. These folds constitute a surface ornamentation, and not lines of growth, as is shown by the fact that they increase in number by intercalation, some folds extending from the anterior to the median portion of the shell, while others extend almost to the posterior end. The principal folds extend to the posterior end and are there sharply flexed. These folds are well defined on the ventral half of the shell and become finer and more crowded on the umbones and almost disappear at the beaks.

This species approaches very closely in general outline and surface ornamentation to *C. alaeformis** Gabb, from the Tejon formation of California, but is less than one-half as large. The concentric folds become finer and more crowded on the umbonal region in the specimen from Chappaquiddick than in that figured by Gabb.

This species also somewhat resembles *C. subengonata*† Dall, from the Eocene of Maryland and Virginia, but differs from that species in being narrower anteriorly and more produced posteriorly, and in the absence of a subcarinate ridge extending from the umbo to the posterior margin. The concentric folds are also more crowded and less prominent on the umbonal region.

The material in hand represents a right and a left valve. These specimens occur in a very fine-grained hard ferruginous luteyite concretion, quite different in character from the material in which most of the other fossils are found.

Anomia simplexiformis sp. n. Pl. VIII, fig. 10, 11.

Shell subovate and prolonged in the region of the beak; left valve very globose, nearly equilateral, somewhat irregular; beak located in median dorsal portion of the shell, submarginal, slightly projecting and incurved; surface without plications or ornamentation, except possibly very faint indications of concentric lines of growth.

* Palaeontology of California, vol. ii, p. 177, pl. xxix, fig. 63.

† Md. Geol. Sur., Eocene, p. 163, pl. xxxii, figs. 1, 1a, 2, 2a, 2b.

A portion of a right valve, probably of this species, is present in a fragment of the ferruginous concretion (fig. 11). It is very much flattened, more or less irregular, with large byssal opening and indications of very faint concentric growth lines.

This species is represented by several complete or nearly complete left valves, varying greatly in size, the length ranging from ten to thirty millimeters. It resembles very closely the modern *A. simplex* from the shores of Long Island. It has the same general outline and shape, and approaches that species in size and in the absence of surface plications and other ornamentations.

Anomia paucistriata sp. n. Pl. VIII, fig. 12.

Shell subcircular, somewhat irregular; left valve convex, nearly equilateral; beak submarginal, dorso-medially placed and not pronounced; surface marked by a few faint radiating striations, crossed and cancellated by very fine concentric lines of growth.

This species is smaller than the preceding, averaging in length about ten to twelve millimeters. It is represented by several left valves. Right valve unknown.

Glycymeris sp. ?. Pl. VIII, fig. 13.

Represented by several internal molds not preserving characters sufficient for specific description. The figure shows the internal characters of the shell and is drawn from a wax imprint made from a mold.

This species is smaller and more ovate in form than *G. idoneus* Conrad, from the Nanjemoy and Aquia formations of Maryland. In size, form and general appearance it resembles more closely *Glycymeris* (*Pectunculus*) *decussatus* Sowerby, from the Eocene of England.

Nucula sp. ?.

Represented by a few small internal molds. In one at least the dental characters are very well preserved. In general outline these resemble very closely *N. potomacensis* Clark, from the Eocene of Maryland, but do not preserve sufficient characters for specific identification or description.

Turritella sp. ?. Pl. VIII, fig. 4.

Shell small, spire high, angle about twenty-five degrees each whorl marked by a distinct, well-defined anterior and less prominent posterior spiral carinate ridge, following around above and below the suture, otherwise the surface is smooth and free from ornamentation; suture distinct; whorls closely placed and rapidly increasing in size.

This species resembles very closely a *Turritella* not specifically identified from the Eocene of Whellock, Texas, in the University collection. The Whellock specimen is larger but has the same apical angle, is free from ornamentation and has the anterior and posterior carinate ridges present but faintly marked.

This description is based on a wax imprint made from a very perfectly preserved external mold in a red micaceous sandstone concretion. The full length of the shell is not represented, so that the number of whorls and dimensions cannot be given. There are no characters of aperture and lips apparent.

Terebra sp. ?. Pl. VIII, fig. 5.

Shell elongate, spire elevated, whorls closely placed, rapidly enlarging, flat on the outer surface between suture, free from ornamentation or with very faint revolving lines, aperture elongate elliptical, pointed anteriorly, rounded posteriorly; outer lip thin and broadly arcuate, inner lip smooth without callus or ridge.

The specimen figured occurs on the edge of a small fragment of rock. The apex is concealed in the matrix and the anterior end of the aperture is slightly injured so that it does not show the minute characters.

Terebra juvenicostata sp. n. Pl. VIII, fig. 6.

Shell small and slender, spire elevated; apex pointed, acute with an apical angle starting at about thirty degrees and decreasing toward the body whorl where the sides of the spire approach to parallelism; the whorls are closely placed and flattened between the sutures. There are distinct ribbings on the earlier whorls which become less distinct along the advancing spire and disappear on the body whorl.

Odostomia semicostata sp. n. Pl. VIII, fig. 7.

Shell small, consisting of six or seven volutions, spire elevated, apical angle thirty degrees; sutures very pronounced; volutions flattened convex between sutures; earliest whorls marked by distinct transverse plications or ribs which become almost or quite obsolete on body whorl; outer lip distinctly denticulate within.

The aperture and columella of this specimen is not fully preserved so it cannot be accurately described. Length of shell as preserved 9.5^{mm}.

Odostomia crenulata sp. n. Pl. VIII, fig. 8.

Shell very small, spire high and closely coiled, apex sub-acute, whorls flattened externally, faintly crenulate along the posterior margin, suture distinct, aperture and lips unknown.

Genus? sp.? Pl. VIII, fig. 9.

Shell small, loosely coiled, apex acute, whorls five or six, well rounded, rapidly increasing in size, smooth without any ornamentation: suture quite deep and distinct, character of aperture and lips unknown.

This species is very similar to a *Limnaea* in shape but can hardly be one of these as it appears to be a salt water form.

Represented in the collection by a small but very perfect external mold of which a wax impression was taken.

Ostrea sp.?

Several small internal molds of representatives of this genus are present among the fragments of the concretion. These are not sufficiently well outlined to be specifically determined. They seem to represent at least two or three different species and all are comparatively very small.

Cardium? sp.?

Several casts doubtfully referred to this genus are to be found among the fragments of concretion collected by Dr. Hollick.

These fossils represent a new and distinct fauna markedly different from that of any other Eocene deposits of this country. Since this fauna does not contain a single species in common with the Eocene faunas of the Atlantic slope and gulf deposits, it cannot be accurately correlated with these beds and assigned its proper place in the geologic scale. Nevertheless from the general characteristics of the contained species and their affinities to forms from widely distant provinces, the horizon of these deposits can be ascertained with some approximation to the truth.

Considering the marine Eocene deposits of this country as a whole, we find that they naturally fall into several provinces lithologically quite distinct, and containing faunas with very few species in common. In New Jersey there is a small and isolated area known as the Shark River beds from their outcrop along that river. According to Clark, these beds represent lower Eocene and rest conformably upon the Cretacic below. By early writers they were considered a part of the Cretacic, as there was no marked line of separation between them and the underlying strata. The fossils, however, were found to be of undoubted Eocene character, and although the fauna was lacking in some of the most widely distributed Eocene species, it still contained no characteristic Cretacic forms.

These Shark River deposits were thought by Harris to represent a higher horizon than the Eocene deposits of Maryland

and Virginia, and Dall, in his correlation tables of the North American Tertiaries, has placed them in the Claibornian stage or equivalent to upper Middle Eocene. The fossils of this province differ so widely from those of the regions immediately to the south that correlation is very difficult, and even now there is doubt as to the exact position of these beds.

A second province of the Eocene, generally known as the Pamunkey formation from its typical development along the Pamunkey River in Virginia, begins in Delaware and extends across Maryland well into Virginia. Lithologically these deposits have more similarities to those of the provinces to the south than to the Shark River beds of New Jersey, yet they are sufficiently distinct both lithologically and in their contained fauna to require complete separation. According to Clark these deposits "constitute a single geological unit."

A third province embraces the Eocene deposits of the Carolinas and Georgia and affords a far more complete series of Eocene strata than either of the more northern areas. The lower beds consist of arenaceous and conglomeratic deposits, rather sparingly fossiliferous, probably because the material by its very nature was not adapted to permit the preservation of fossils. The middle and upper beds are well developed and represented by limestones and marls containing an extensive fauna, yet quite distinct from the surrounding provinces.

A fourth, the Gulf province, is by far the most extensive of the Eocene areas. It extends from Florida to Texas and includes the so-called Mississippian embayment, an area extending well up into the Mississippi basin. All stages of the Eocene are more fully represented, but both lithologically and paleontologically this province is very distinct from those along the Atlantic coast. Peculiar conditions in this area resulted in the interbedding among the other deposits of many lignitic strata.

A fifth marine Eocene province occurs along the Pacific coast, and outcrops along the coastal range in California, Oregon and Washington. These deposits are generally known as the Tejon group and were originally referred to the Cretacic. Later study has shown them to be of Eocene age, and yet their fauna differs widely from those of the Atlantic and Gulf provinces.

The fauna from Chappaquiddick represents a new and distinct Eocene province, differing from all the other provinces but no more widely different from these than they are from one another. Although in this fauna there are several species somewhat resembling those of the provinces to the south, on the whole it would seem to be more closely allied to the Eocene of England. The genera most abundantly represented

in these Chappaquiddick deposits, e. g., *Modiola*, *Glycymeris*, are also among the most abundant in the English deposits. These same genera, although represented in the Atlantic and Gulf provinces, are there more sparsely distributed and occur with other more abundantly represented genera that appear to be altogether wanting in the Chappaquiddick deposits.

A comparison of this Chappaquiddick fauna with other Eocene faunas indicates that it is of lower Eocene age, the species most closely resembling those found in this fauna being found in the lower beds of the Atlantic and Gulf provinces, the Tejon of California and the lower beds of England. These deposits may possibly be of the same age as the Shark River beds of New Jersey, but being deposited in a region separated from this have no forms in common with it, but such correlation could be only conjecture. As the correlation of the well known Eocene deposits is even yet very uncertain, it is unnecessary and impossible to place these beds any more definitely than simply to say they are lower Eocene.

Columbia University, New York City.

EXPLANATION OF PLATE VIII.

FIGURE 1.— <i>Modiola vineyardensis</i>	p. 232
FIGURE 2.— <i>Modiola hollicki</i>	p. 232
FIGURE 3.— <i>Corbula Whitfieldi</i>	p. 233
FIGURE 4.— <i>Turritella</i> sp. ?	p. 234
FIGURE 5.— <i>Terebra</i> sp. ?	p. 235
FIGURE 6.— <i>Terebra juvenicostata</i>	p. 235
FIGURE 7.— <i>Odostomia semicostata</i>	p. 235
FIGURE 8.— <i>Odostomia crenulata</i>	p. 235
FIGURE 9.—Genus ? sp. ?	p. 236
FIGURES 10 and 11.— <i>Anomia simplexiformis</i>	p. 233
FIGURE 12.— <i>Anomia paucistriata</i>	p. 234
FIGURE 13.— <i>Glycymeris</i> sp. ?	p. 234

ART. XXVII.—*The Production of Radium from Uranium;*
by BERTRAM B. BOLTWOOD.

THE hypothesis that radium is a disintegration product of uranium has been greatly strengthened through the demonstration of the fact that in radio-active minerals the quantity of radium is directly proportional to the quantity of uranium present.* On the basis of the disintegration theory a proportionality of this sort is to be expected between the parent element and its radio-active successor.

Additional data on this highly important question are however desirable, and a single experiment likely to further elucidate the problem has been independently undertaken by a number of different investigators. This experiment consists in observations conducted on a carefully purified uranium salt with a view to determining whether, with the lapse of time, measurable quantities of radium will be produced within it. If radium is a *direct* product of uranium through the intermediate stage of uranium-X and if the average life of radium is approximately 1,000 years, then it can readily be deduced that, with the delicate methods of measurement at command, the quantity of radium formed in a few hundred grams of uranium salt will be readily detectable and measureable after the lapse of a period no longer than a month. If, however, one or more transition products of a relatively slow rate of change intervene between the substance uranium-X and radium, the production of radium will be so protracted that no quantity of it sufficiently great to permit its detection will be formed within a greatly extended period.

The difficulties involved in the experimental demonstration of the growth of radium do not appear to be great. Uranium forms no radio-active, gaseous disintegration product, while the radium emanation affords a most convenient means of quantitatively estimating any radium which may be present. A solution of a carefully purified uranium salt can therefore be prepared and can be tested at intervals for radium emanation. If radium is formed from the uranium its existence will be indicated by the presence of radium emanation in the uranium solution.

Three papers in which an experiment of this character is described have been published by Mr. Soddy.† In the first

* Boltwood, *Phil. Mag.* (6), ix, 599; Strutt, *Proc. Roy. Soc. Lond.*, lxxvi, 88; McCoy, *Berichte d. deutsch. chem. Ges.*, xxxvii, 2641.

† "The Life-history of Radium," *Nature*, lxx, 80; "The Origin of Radium," *Nature*, lxxi, 294; "The Production of Radium from Uranium," *Phil. Mag.* (6), ix, 768. Mr. Whetham has also published two contributions on the same general topic (*Nature*, lxx, 5; *ibid.*, lxxi, 319) in which he states

paper, published May 12, 1904, very scanty details of the experimental procedure are given, but a summary of the conclusions reached at that time by the author is as follows:

1. The quantity of radium which has accumulated in one kilogram of uranium nitrate in twelve months is less than 10^{-11} gram.

2. The question so far as the production of radium *from uranium* is concerned is practically settled.

3. If uranium changes into radium, less than one ten-thousandth part of the theoretical quantity is produced during the first year's accumulation.

4. The evidence may be taken as indicating that uranium is not the parent element of radium.

The second paper, published Jan. 26, 1905, eighteen months from the commencement of the experiment, is likewise lacking in a detailed account of the experimental methods, but the author states that measurements carried out at that time with the kilogram of uranium nitrate under observation indicate that it contains 1.5×10^{-9} gram of radium, a quantity which, while of considerable relative magnitude, is only one five-hundredth of the amount to be expected from the disintegration theory on the assumption of a direct change. The author suggests that the greater part of the radium emanation may (under the conditions of the experiment) be retained in the uranium solution and not evolved as a gas. On the basis of the amount of radium assumed to be then present it is deduced that the fraction of uranium changing per year is 2×10^{-11} .

After pointing out certain sources of error likely to have exercised a disturbing influence during the elapsed period of observation, the author adds,—“if the whole series of measurements from the commencement are recalculated, eliminating the error alluded to, they are fairly consistent with there having been a steady production of radium at this rate continuously from the commencement.” One of the sources of error alluded to was the introduction of very considerable quantities of radium salts into the laboratory during the period when the kilogram of uranium nitrate was under observation. It is stated that the presence of this radium greatly disturbed the electroscope in which the measurements were conducted. Additional difficulty had been previously experienced in attempting to standardize the measuring instrument with the emanation corresponding to a known weight of pure radium salt.

that he also believes that he has observed indications of the growth of radium in uranium compounds. Since Whetham's communications contain neither any account of experimental details nor any record of quantitative measurements, it is impossible to judge as to the value of the data on which the author's conclusion is based.

The third and more elaborate article by the same author appeared in the June number of the *Philosophical Magazine*. The data briefly given in the earlier articles are here treated at greater length and a closer insight can be gained of the experimental methods and the results on which the author's later conclusions are based. Although it is stated in this paper that observations had been taken occasionally over a period of eighteen months and that these observations indicated a *gradual* growth of the emanating power of the uranium solution, the only definite and directly comparable numbers are restricted to a total period of about three weeks (Dec. 17, 1904 to Jan. 9, 1905) and include only four measurements conducted at the close of the period of observation.

Without entering into a discussion of various minor details in Mr. Soddy's papers, it is desired to call particular attention to the following important considerations in relation to the experimental data submitted :

First. No conclusive evidence is brought forward to show definitely how much or how little radium was present in the uranium solution at the commencement of the experiment.*

Second. It appears extremely possible that the increase in the content of radium which Mr. Soddy believes he has observed in his uranium solution may in fact have been due to the accidental and unconscious introduction of radium salts during the tests conducted at the end of the twelve months period. According to his own statements these tests were carried out in a laboratory notably contaminated with various radio-active products, and the accidental introduction of the sub-microscopic quantity of material (1.6×10^{-8} gram.) which was afterwards detected would account for the later positive results. The liability of contamination from an extraneous source is strongly suggested by the behavior of Mr. Soddy's electroscope, in which the normal air leak has risen from 0.048 division per minute to 1.56 division per minute, an increase of over thirty times, during the period covered by his experiments.

The conditions essential to the elucidation of the question of the actual production of radium in uranium compounds would seem to be :

* The writer of the present paper convinced himself at the beginning of his own experiments that the method of procedure followed by Mr. Soddy in testing his solutions for radium emanation is entirely unsuited for the determination in question. A concentrated solution of incompletely purified uranium nitrate containing traces of radium gave up only a fraction of the total radium emanation generated within it when the solution was allowed to stand for days in contact with a small air space and air was bubbled through it. It was speedily found that only by boiling the solution vigorously for about fifteen minutes could the total emanation present be positively separated.

(a) The employment of a method for the determination of radium which gives positive and quantitative results. The method must be suitable for the determination of very small quantities of radium and must be capable of indicating the *maximum* quantity present at all times.

(b) The preparation of a pure compound of uranium and the demonstration that the compound is initially free from radium.

(c) Proper conditions for testing and preserving the uranium salt in order to preclude the introduction of radium or radium emanation from external sources, so that if the presence of radium is noted it can be assumed with certainty that the radium found has actually been formed in the solution.

It would appear that none of these essential conditions has been fulfilled in the experiment described by Mr. Soddy.

The writer of the present paper has been conducting an experiment on the growth of radium in a uranium solution for the past thirteen months. The conditions of the experiment were the following: In May, 1904, a kilogram of "purest uranium nitrate" was purchased from Eimer & Amend of New York City. This material was tested qualitatively for radium (through the emanation) and readily detectable quantities of this element were found to be present. The salt was dissolved in distilled water and the solution was filtered. The compound was then recrystallized five separate times, the conditions being so chosen that the separate crystals of each of the different crops were not over two millimeters in cross-section. The mother liquors were each time removed from the crystals on a suction filter, and the crystals were washed with a small quantity of ice-cold water.

The final yield of purified material was a little in excess of 200 grams. Of this 100 grams were taken and dissolved in pure, distilled water. This solution was introduced into a glass bulb with a capacity of approximately 400^{cc}, diluted to about 250^{cc}, and the neck of the bulb was drawn out into a short capillary and sealed in the flame of the blowpipe. The solution was sealed up on July 8, 1904. Thirty days later the bulb was opened under conditions which precluded the escape of any portion of the contained gases and the entire gaseous contents were removed and transferred to an electroscope. In order to completely displace the dissolved gases and any radium emanation which might have been present the solution was boiled vigorously for about fifteen minutes.*

*The removal and collection of the gaseous contents of the bulb was accomplished by the use of the apparatus which has been described in a previous paper (this Journal, xviii, 379). The neck of the bulb containing the uranium solution having been first notched with a file, it was inserted in the rubber tube D, the point was broken off within the tube, and the gases displaced from the bulb on heating were collected in the burette D, which was filled at the start with boiling water.

The type of electroscope used in this investigation has already been described (this Journal, xviii, 97). The emanation from the radium associated with 0.1 gram of uranium in a radio-active mineral caused a leak of approximately 21 divisions per minute. Assuming that the 100 grams of uranium nitrate contained 48 grams of uranium, the leak corresponding to the quantity of radium in radio-active equilibrium with 48 grams of uranium would be approximately 10,000 divisions per minute. The normal air leak of the instrument was 0.012 division per minute, and an increase of 0.005 division per minute could have been detected with certainty. The electroscope was therefore capable of indicating the presence of a quantity of radium equal to 5×10^{-7} of the equilibrium quantity. The actual quantity of radium equivalent to a leak of 0.005 division per minute was 1.7×10^{-11} gram.*

On introducing the gases present† in the uranium solution into the electroscope *no increase* in the leak of the instrument could be detected although the observations were continued over a period of eight hours. The quantity of radium present at the start was therefore less than 1.7×10^{-11} gram.

The uranium solution in the bulb was allowed to cool, and the neck of the bulb was again sealed. At the end of six months from the start, in January, 1905, the uranium solution was again tested under conditions identical with those under which the first test was carried out. Entirely negative results were obtained and the quantity of radium then in the solution was still less than 1.7×10^{-11} gram. A similar test was conducted on August 2, 1905, 390 days from the commencement, and no evidence of the presence of radium emanation was even then obtained. It can therefore be positively stated on the basis of sound experimental data that in 390 days the quantity of radium formed from 48 grams of uranium in a uranium nitrate solution is less than 1.7×10^{-11} gram.

The quantity of radium which can have been produced in the given time is therefore less than one two-millionth of the equilibrium quantity and less than one sixteen-hundredth of the quantity which would be expected from the disintegration theory if the value of λ for radium is taken as 8.8×10^{-4} (year)⁻¹.‡ The quantity is furthermore only about one-tenth of the quantity assumed by Mr. Soddy to have been formed from an equal quantity of uranium in his solution during an interval of eighteen months.

It is important to add that the whole series of measurements has been conducted in a laboratory which has been carefully

* Rutherford and Boltwood, this Journal, xx, 55.

† At the end of the 30-day period.

‡ Rutherford, Trans. Roy. Soc. London, (A) cciv, 215.

protected from contamination by the salts of radium or other radio-active substances, and that the electroscope used has been reserved for this particular research, its original normal air-leak having remained unaltered throughout the entire period. It has therefore been unnecessary to introduce any corrections or to make any allowances for possible errors due to known causes of any description.

The experiments described in this paper are considered to indicate that the results obtained by Mr. Soddy are without significance and that one or more products of a slow rate of change intervene between uranium and radium.

It is claimed, moreover, that the conclusions in Mr. Soddy's first paper, so far as they relate to the *direct* transformation of uranium into radium, are more truly in accord with the actual facts than are those contained in his later publications.

139 Orange street, New Haven, Conn.
August, 1905.

SCIENTIFIC INTELLIGENCE.

I. GEOLOGY.

1. *Explorations in Turkestan with an account of The Basin of Eastern Persia and Sistan. Expedition of 1903, under the direction of RAPHAEL PUMPELLY.* 4to, 324 pp., 6 pls., 174 figs in text. Washington, D. C. (Published by the Carnegie Institution of Washington. Publication No. 26. April 1905.)—This publication contains the following five papers: Archeological and Physico-Geographical Reconnaissance in Turkestan by Raphael Pumpelly; A Journey across Turkestan by William M. Davis; Physiographic Observations between the Syr Darya and Lake Kara Kul, on the Pamir, 1903, by Raphael W. Pumpelly; A Geologic and Physiographic Reconnaissance in Central Turkestan, by Ellsworth Huntington; The Basin of Eastern Persian and Sistan, by Ellsworth Huntington.

Professor Pumpelly states in the introduction that "At the end of 1902 the Carnegie Institution voted a grant to me 'for the purpose of making, during the year 1903, preliminary examination of the Trans-Caspian region, and of collecting and arranging all available existing information necessary in organizing the further investigation of the past and present physico-geographical conditions and archeological remains of the region.'

"The investigation was proposed because (1) there is a school that still holds the belief that central Asia is the region in which the great civilizations of the far East and of the West had their origins; and (2) because of the supposed occurrence in that region, in prehistoric times, of great changes in climate, resulting in the formation and recession of an extensive Asian Mediterranean, of which the Aral, Caspian, and Black seas are the principal remnants.

"It had long seemed to me that a study of Central Asian archeology would probably yield important evidence in the genealogy of the great civilizations and of several, at least, of the dominant races, and that a parallel study of the traces of physical changes during Quaternary time might show some coincidence between the phases of social evolution and the changes in environment; further, that it might be possible to correlate the physical and human records and thus furnish a contribution to the time scale of recent geology.

"At my request Professor William M. Davis assumed charge of the physico-geographical part of the preliminary reconnaissance."

In concluding he remarks that "We have shown that the recent physical history of the region is legibly recorded in glacial sculpture and moraines, in orogenic movements, in valley cutting and terracing, in lake expansions, and in the building up of the

plains, and we have made some progress in correlating these events.

"We have also found full confirmation of the statements as to a progressive desiccation of the region of long standing, which has from a remote period continually converted cultivable lands into deserts and buried cities in sands.

"We have found, widely distributed, great and small abandoned sites of human occupation, with evidences of great antiquity.

"We have reason to think that a correlation of these physical and human events may be obtained through a continuance of the investigation, and that archeological excavations will throw light on the origin of Western and Eastern civilization."

In the second article Professor Davis describes his observations upon the Caspian region with its abandoned shore lines up to 600 feet above the present water-level, and the traces of the Pliocene sea whose deposits, as the Russian geologists have shown, underlie the plains of southern Turkestan. He says of the Piedmont plains that: "Since the withdrawal of the Pliocene sea, the eastern and southern borders of the plains of southern Turkestan appear to have been aggraded by the rivers that flow out upon them from the mountains. That a certain measure of such constructive action has taken place is announced by the Russian geologists, but it is not apparent that the full measure of river action has been recognized. Some of the strata of the plains are said to be not fluvial but lacustrine, because they are of fine texture and uniform structure, without the variable layers of gravel that are by implication supposed to be always indicative of river work; but this seems to be a simpler solution than the problem deserves. There are many rivers that do not carry gravel, and there are many river plains whose smooth surface must receive very even and uniform deposits of flood-laid silts over large areas. Records of boring are quoted by Walther which show river muds on sand and loess to a depth of nearly 50 meters beneath the bed of the Amu River at Charjui, where the great railroad bridge was built. The record of a well boring at Askhabad, quoted by the same author, shows variable piedmont deposits over 2,000 feet deep. It seems, indeed, as if we had in the plains of Turkestan and the Great Plains of our West one of the most striking of the many physiographic resemblances between Eurasia and North America; and that there as well as here an increasing share may be given to the action of aggrading rivers in forming the plains, as observations are extended. It is well known that the tide of geological opinion in this country has in recent years turned more and more toward a fluvial origin for the strata of the Great Plains that slope eastward from the Rocky Mountains, and the traditional lacustrine origin of the plains strata has been repeatedly questioned; so we may expect, as closer attention is given to the details of river-laid formations, that a larger and larger share of the fresh-

water strata that slope westward from the mountains of Central Asia may be interpreted as fluvatile rather than as lacustrine."

"The irregular structure of the piedmont slope, as exposed in cuts along the railroad line, is well described by Walther. There is a frequent and irregular alteration of stratified or massive loess-like clay, finely stratified sands, and coarse gravel, with many local unconformities; all this being the result of the variable action of floods that sweep suddenly, unguided by channels, down the piedmont slope; now eroding, now depositing; here sweeping along coarse blocks, there depositing fine silts. Ten miles south of Askhabad, where the railroad station is 819 feet altitude, we saw, when returning by the Meshed road from an excursion in the Kopet Dagh, more abundant piedmont deposits of mountain-waste dissected to depths of several hundred feet. A great thickness of these deposits has been penetrated by the artesian boring in the suburbs of Askhabad, already mentioned, 2000 feet deep, and therefore with more than half its depth below sea level, but without securing a water supply. The whole depth, as shown in the record quoted by Walther, is in variable layers of clay, sand, and gravel, similar to the deposits seen in the harrow-pits near the railroad embankments, or in the natural sections; and all of this heavy deposit is therefore best explained by conditions and processes like those of to-day during persistent depression of the surface. The failure to secure a water supply from this deep well is in itself very suggestive of the irregular underground structures and of their torrential origin."

An excursion into the Kopet Dagh and the mountains of Persia revealed abundant evidence of sub-recent terracing in the valleys of a character to suggest a relative uplift of the heart of the chain. The desert plains from Askhabad to Samarkand are characterized by aggrading rivers. "The most notable feature of this district was the absence of valleys. The rivers have channels in which their waters are usually restrained, but there were no valleys in which the river floods were limited. The plains were open to overflow as far as flood supply held out. We were told, however, that some distance upstream (to the south) the Murg-ab has a flood-plain slightly depressed beneath the plain. This we interpreted as meaning that the river had there changed its habit from aggrading to degrading. On crossing the Amu at Charjui we saw a low bluff on the north or right of its course, although on the south the plain is not significantly above the river.

"The general absence of valleys is a natural, indeed an essential, feature of a fluvatile plain in process of aggradation by flood deposits. It is peculiarly appropriate to rivers like the Tejen and Murg-ab, which dwindle away and end on the plain, so that every grain of sand and every particle of silt must be laid down as the water volume lessens and disappears. The absence of valleys would, on the other hand, be surprising in a

lacustrine or a marine plain, for the reason that coincidence could hardly be expected between the slope that might be given to such a plain when it is laid bare and the slope that is satisfactory to the graded rivers that run across it. It is not, however, as has already been pointed out, always the case that fluvial plains have no valleys eroded beneath their general level. The river-made plains of northern India are now commonly somewhat trenched by their rivers. Our Great Plains, piedmont to the Rocky Mountains, are likewise in process of dissection by their rivers. The plains of Turkestan are therefore somewhat exceptional in this respect. As a result we had unfortunately no opportunity of seeing sections of the plains in which the structure of the deposits could be examined. A well on the Czar's estate at Bairam Ali, a modern village near Old Merv, where we were most agreeably entertained by the superintendent, Mr. Dubassoff, was said to have shown nothing but 'sand and loess.' The desert and river deposits found by borings beneath the Amu River beds at Charjui have already been noted. The inspection of these vast plains of silt was very suggestive in connection with the problematic origin of the fresh-water Tertiary formations of the western United States. Certainly no one who sees the river-made area of the plains of Turkestan can doubt the capacity of rivers to lay down extensive fine-textured deposits."

In regard to the Tian Shan mountains Professor Davis states that "A number of the mountain ranges that we saw were of vigorous form, with sharp peaks and deep-carved valleys, in which it was impossible to recognize any trace of the original unsculptured mass; but certain observations made in the central and northern ranges, near Lakes Son Kul and Issik Kul, and on the steppes that border the mountains on the north, led to the belief that the region had been very generally worn down to moderate or small relief since the time of greater deformation, which probably occurred in the Mesozoic age; that large areas of subdued or extinguished mountain structures are still to be seen in the low ranges and in the steppes north of the Ili River; and that the present relief of many of the higher Tian Shan ranges is the result of a somewhat disorderly uplift and of a more or less complete dissection of dislocated parts of the worn-down region. Mr. Huntington's report shows the application of these conclusions to a large part of the central and southern Tian Shan." The space devoted to a notice of so wide ranging a report forbids further detailed mention of the numerous observations of the author upon river and glacial phenomena of the valleys of the Tian Shan.

In the article by Mr. Pumpelly, an account is given of the Kara Kul, a lake of bitter salt water, and its desert shores, and also a good description of the moraines in the mountains. Indications of two long-separated ice advances were noted and signs of a feeble third. Variations of lake level and ice advance are attributed to climatic control. Evidence is discussed

to support the supposition that in early Pleistocene time the Alai mountains wasted down until a detritus-covered piedmont plain formed on the north of the range, whereupon a dislocation seems to have occurred nearly parallel to the range and north of it with sinking of the plains still farther north or with uplift of the range. The relations of the river work to this change of altitude are briefly explained.

In his article on central Turkestan Mr. Huntington gives a summary of the geology and topographic development. Of the Paleozoic series he states: "In Central Turkestan a single succession of strata is repeated again and again, with only slight local modifications. The oldest observed formation is an ancient white marble, shot through and through with intrusions of granite. It was noticed only in the Alai Mountains in the neighborhood of Kok Su and Karategin. Its junction with the overlying formation was not seen, but the contact presumably shows an unconformity, as a conglomerate near the base of the covering strata contains pebbles of the marble. The granite which is intruded into the marble is of much later date, for it occurs abundantly in the Paleozoic series in the ridges of the Tian Shan plateau and along the north side of the Alai range. The main body of the Paleozoic series is a great thickness of limestones, many of them slaty, which are stated by Tchernachef to be of Devonian and Carboniferous age. They are greatly folded and have been penetrated not only by granite intrusions, but also by some basaltic lavas, as may be seen, for instance, in the Sugun Valley west of Shor Kul. The folding of the Paleozoic strata is of the sort which is associated with mountain building, hence at the end of the Paleozoic era or in the early part of the Mesozoic this part of Central Asia must have been highly mountainous. In evidence of this it may be pointed out that the succeeding unconformable conglomerates are so coarse that they could only have been formed subaerially in a region of considerable relief, and yet at the time of their deposition the old folds of limestone and slate had already suffered great denudation. As a rule, the hard Paleozoic strata are found in the highlands, while the softer Mesozoic and Tertiary strata occur in basins among the highlands and mountains; but this seems due less to the superior resistance of the older rocks than to the fact that they were bent down where they are covered, and that the younger strata were largely formed in the very basins which they now occupy."

"The conditions under which the Mesozoic-Tertiary series were deposited seem to have been largely subaerial, or at least non-marine. The coarse conglomerates at the base probably indicate arid or semi-arid conditions in a region of considerable relief. As relief grew less, or as the climate grew moister, the gravel of the conglomerate gave place to sand, and that in turn to shale; in the latter are four or five coal seams. The next period, that of the vermilion beds, seems to have opened at a time of sub-

aerial deposition when the conglomerates and the cross-bedded sandstones were formed; but toward the end the encroachment of the sea is indicated by the deposition of the marls and fossiliferous limestones. Elsewhere throughout the whole Mesozoic-Tertiary series fossils seem to be wholly absent, although the deposits are well fitted to preserve the remains of plants and animals if any had existed; but here the calcareous strata, which show other evidences of being marine, contain fossils in abundance. Above the limestones the strata are at first red, as though the shallowing of the sea allowed the very highly weathered soil of an old land mass to be washed farther and farther out into the area of deposition. The succeeding formations, the pink and brown sandstone and the brown conglomerate, show a nearer and nearer approach to present conditions. It appears as though, after the retirement of the sea, the land was covered with great playas, on which water first stood in thin sheets, forming ripple-marks in the mud, and then retired or was evaporated, allowing the surface to become sun-cracked. As time went on streams began to flow across the playas, at first slow and broad and able to cut only shallow channels, which were afterwards filled and covered, assuming the form of very thin lenses of a material slightly different from that of the surrounding playa strata. Then, as the strength of the streams increased, sand was deposited over the whole area, and the channels, now deep and distinct, were filled with gravel. Lastly, gravel was deposited almost everywhere."

Central Turkestan exhibits a recently warped and elevated peneplain the dissection of which is assumed to have begun in the closing Tertiary, though the uplift is placed mainly in Pleistocene time. Summit glaciers were found among the mountains between Marghilan and Issik Kul. From his observations upon the ancient moraines of these glaciers the author concludes that: "Wherever old moraines are well developed they indicate that the glacial period is divisible into two or more subdivisions; and where the valleys are large and reach high enough still to contain glaciers the number of these subdivisions is five, marked by successive moraines, each of which is smaller and at a greater altitude than its predecessor. Two theories present themselves as worthy of consideration in explanation of these facts. According to one there was but a single glacial advance and retreat. The retreat was not accomplished uniformly or rapidly, but by successive steps, after each of which there was a long pause that gave opportunity for the accumulation of a moraine; thus five moraines were formed by each glacier and those now in process of deposition belong to the sixth step of the same long retreat. According to the other theory, each moraine represents a distinct glacial epoch, during which the glaciers first advanced and then retreated. Under this theory the intervals of retreat were as warm as or warmer than the present and the ice retreated far into the mountains during each of them.

"For fifteen out of the twenty-four glaciated valleys examined the first theory is sufficient, but it will not explain the other nine. In eight of these nine valleys one or more of the older moraines lies upon a topography different from that of to-day, so as to suggest that the moraines and the floor on which they rest have been trenched by a valley of stream erosion. In this valley lie the younger moraines, leaving the older moraines as terraces which extend beyond the later moraines both up-valley and down-valley; the up-valley extension of the morainic terrace gives a minimum measure of the retreat of the glacier during the interglacial epoch. In the ninth valley a detached portion of an older moraine lies far up-valley from its successor and even above the main part of the modern moraine. These facts are to be explained only by supposing a glacial retreat and advance in each interglacial epoch, and hence a warmer interglacial epoch between colder glacial epochs. Another sort of evidence of a warmer interglacial epoch is found where one moraine lies upon its predecessor in an attitude which indicates that before the deposition of the younger moraine the older one was first an area of erosion and later of deposition. All these facts accord with the theory of successive advances and retreats, and thus warrant the division of the glacial period into several glacial and interglacial epochs. In one place or another signs of an interglacial retreat are found between each successive pair of the four earlier moraines, while the fifth moraine stands apart from the others, except at Kan Su, where the time during which there is evidence of retreat may be either between the third and fourth or fourth and fifth advances of the ice. Everywhere the climate of the successive glacial epochs seems to have grown less severe, and the duration of the interglacial epochs seems to have diminished in the same ratio."

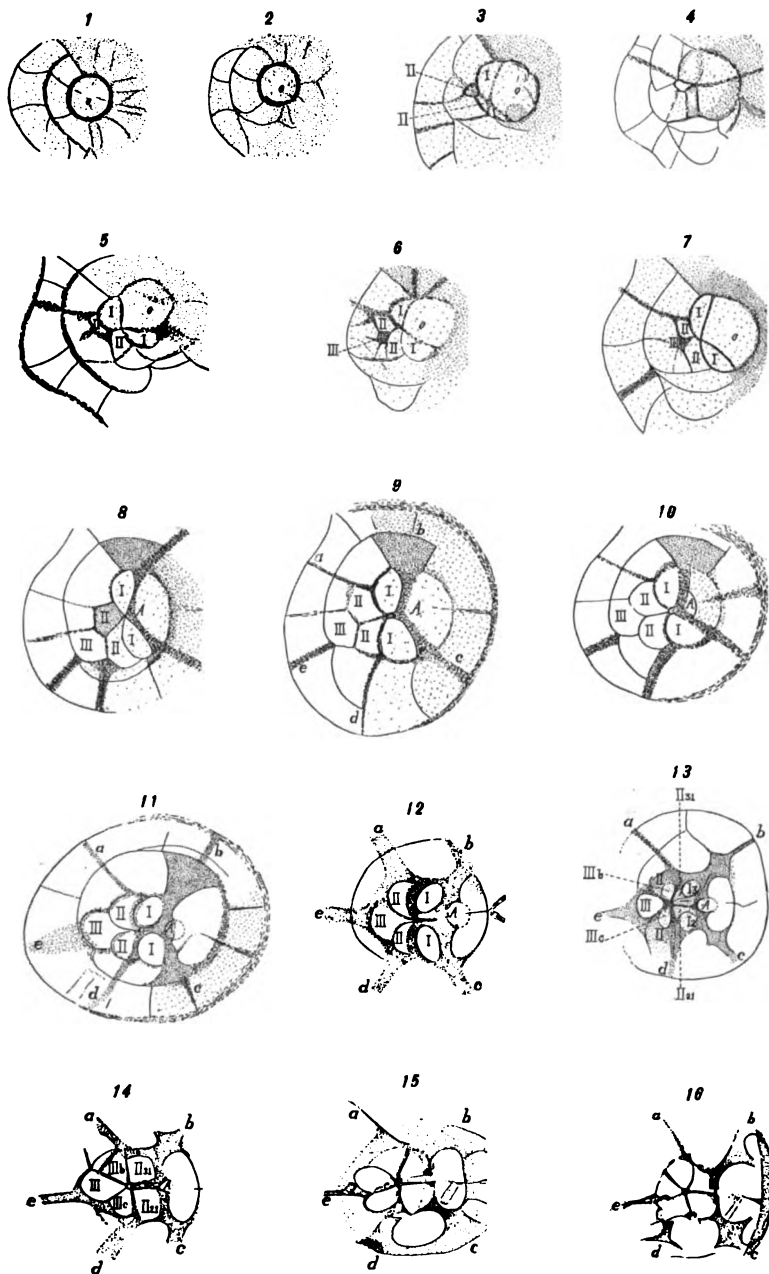
A succession of terraces found in the valleys are regarded as the result of a climatic change. The number of climatic swings thus inferred agrees essentially with the series of cold epochs based upon the occurrence and distribution of moraines. He states: "The essential point in our study of the recent geological history of Turkestan is this: From three separate lines of reasoning, based on the allied yet distinct phenomena of glaciation, terracing, and lake expansion, we arrive at the same conclusion, namely, that during the Quaternary era there have been a number of colder or glacial epochs, five or more, separated by warmer interglacial epochs when the climate was similar to that of to-day; and further, that these epochs progressively decreased in length and intensity."

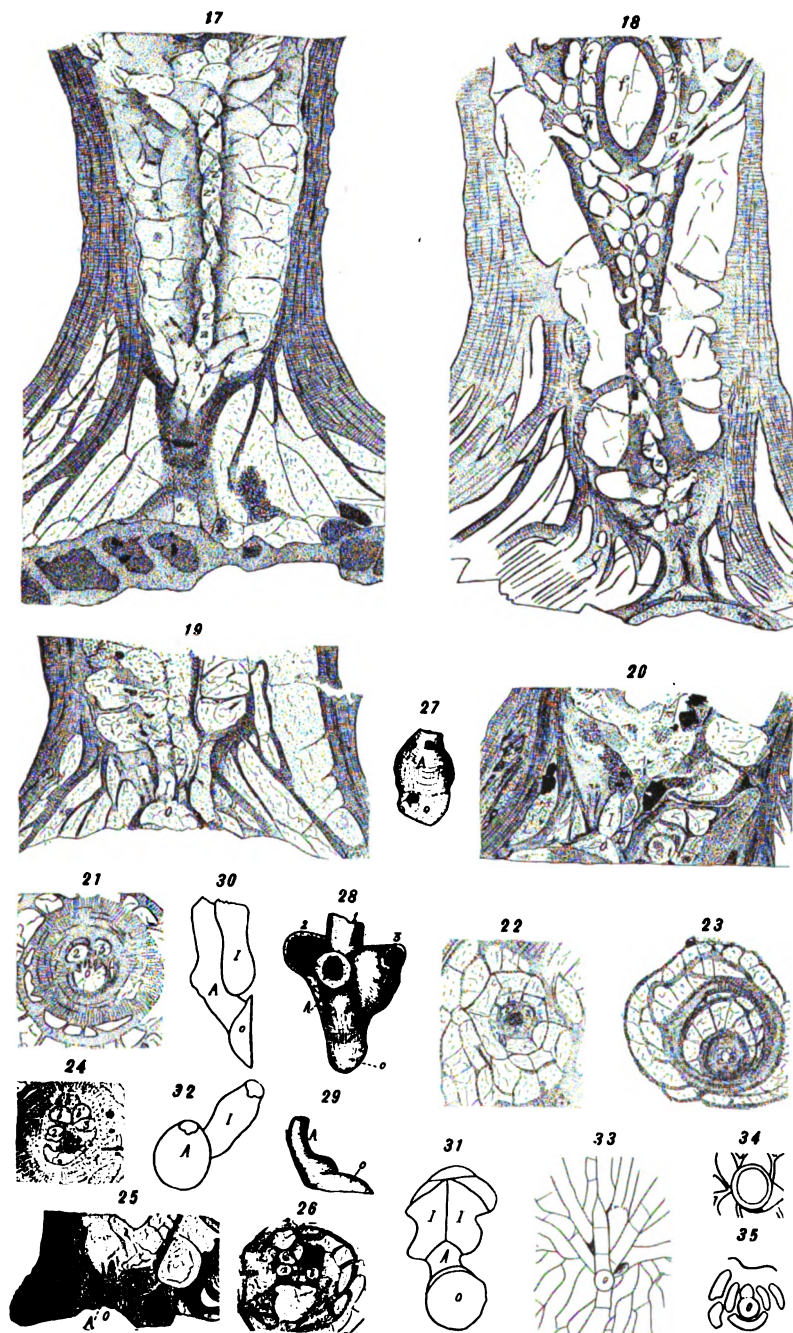
In the final article on the basin of eastern Persia and Sistan Mr. Huntington discusses briefly the geology and in a more complete way the physiography of this desert basin. In a summary paragraph he states: "The facts set forth above, so far as they warrant any conclusion, suggest that in Eastern Persia the lower strata of the basins are generally greenish shales, which are now exposed along the edges of the basins where they have been

extensively warped and compressed. Above them occur reddish silts containing more or less sand and gypsum and warped like the underlying shales, although to a less extent. In certain places toward the top of the series the red strata alternate with green clays. Above all lie the deposits of silt and gravel which are to-day accumulating. Although these different strata show varying degrees of warping along the edges of the basins, it is noticeable that toward the centers they approach the horizontal position. It is probable that in the centers of many of the basins an uninterrupted series of strata has been deposited from the time of the post-Cretaceous uplift of the country until now. At first a shallow sea or large lakes probably occupied the central portions of Iran and allowed the deposition of the green shales. Later, as the great basin was broken into smaller basins, the larger bodies of water gave place to smaller ones, and these, under the influence of a dry climate, gave place to playas or shallow salt lakes where the prevailing deposits were reddish silts. Still the process of deepening the basins and decreasing their area went on, with the result that the green shales were more highly warped and the red deposits were also uplifted along the borders of the basin and were exposed to erosion. Meanwhile the superficial deposits which now cover the plains were laid down and the country assumed its present form. It is not to be supposed that every basin has gone through exactly the same process, or that a single process has everywhere taken place at the same time. Accidents have intervened. At Zorabad the damming of the Heri Rud formed a lake and greatly altered the course of events. At Sistan, and probably elsewhere, a series of lakes appears to have occupied the basin during the glacial period. Nevertheless the general course of events was a gradual progress from larger basins to smaller basins, and from subaqueous to subaerial deposition."

The report is well illustrated and its publication in this country cannot but help correct the too great reluctance of American geologists to depart, in their interpretation of the continental deposits of western America, from the traditional invoking of those processes which in the infancy of geology were the sole known agencies of change because they are the controlling ones in its birthplace. The English geologists in India and Persia long ago pointed out the magnitude and characteristics of the reproductive work of rivers, and of the changes going on in arid regions; and Mr. Huntington well observes that the likeness of the physical history in Central Asia and the western and southwestern portions of the United States is now and has been in the course of geological time very striking both in product and process.

J. B. W.





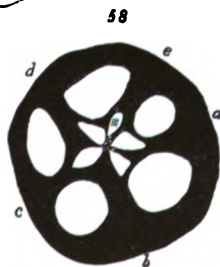
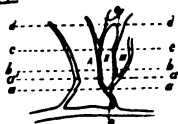
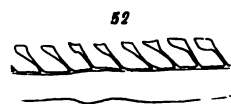
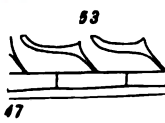
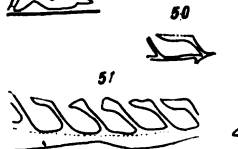
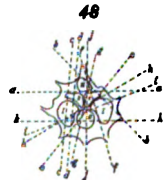
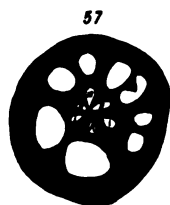
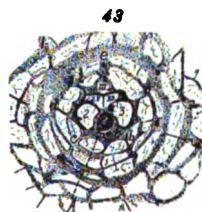
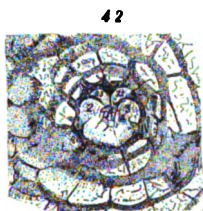
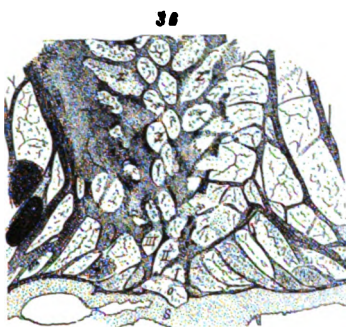




FIG. 1, $\times \frac{1}{2}$.



FIG. 2, $\times \frac{1}{2}$.



FIG. 3, $\times \frac{1}{2}$.



FIG. 4, $\times \frac{1}{2}$.



FIG. 5, $\times \frac{1}{2}$.



FIG. 6, $\times \frac{1}{2}$.



FIG. 7, $\frac{1}{2}$.



FIG. 8, $\frac{1}{2}$.



FIG. 9, $\frac{1}{2}$.



FIG. 10, $\times \frac{1}{2}$.

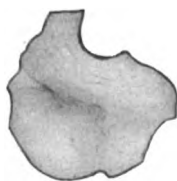


FIG. 11, $\frac{1}{2}$.



FIG. 12, $\times \frac{1}{2}$.



FIG. 13, $\times \frac{1}{2}$.

T H E

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVIII.—*On the Ultimate Disintegration Products of the Radio-active Elements*; by BERTRAM B. BOLTWOOD.

IN a paper by Rutherford and Soddy,* the authors have called attention to the probability that an intimate knowledge of the composition of radio-active minerals will lead to the recognition and identification of the ultimate, stable products formed by the disintegration of the relatively unstable radio-active elements.†

It is an extremely impressive fact that it was from the somewhat meager information available on the occurrence of helium in radio-active minerals, and from the consideration of the data derived from the experiments of one of them on the nature of the expelled alpha particle, that in 1902 the same authors were enabled to make that brilliant prediction of the production of helium‡ which was afterwards confirmed by the experiments of Ramsay and Soddy.

The natural minerals represent chemical systems which are in most instances of extreme antiquity, their original formation having frequently taken place during the earliest geological periods of our planet. With the assistance of the data supplied by geology and mineralogy, it is often possible to assign the origin of a given mineral to some definite geological period and to arrange a series of different individuals roughly in the order

* Phil. Mag. (6), v, 576 (1903).

† "In the naturally occurring minerals containing the radio-elements these changes must have been proceeding steadily over very long periods, and, unless they succeed in escaping, the ultimate products should have accumulated in sufficient quantity to be detected, and should therefore appear in nature as the invariable companions of the radio-elements."—*Rutherford and Soddy, loc. cit.*

‡ Phil. Mag. (6), iv, 582.

of their production, obtaining in this manner an approximate knowledge of their relative ages. In dealing with the question of radio-active change, where the element of time is such an important factor in the solution of nearly every problem, the advantages to be derived from the careful study of the radio-active minerals can therefore scarcely be overestimated.

From a knowledge of the chemical properties and the crystallographic, optical and other physical properties of a given mineral specimen, together with an understanding of its occurrence and of the other mineral substances with which it is found associated, it is generally possible to definitely determine whether the mineral was formed simultaneously with the mass of material or geological formation in which it now occurs, or whether it is of more recent production, having originated through the action of percolating waters or of subterranean vapors or gases on some original constituent. In the former case, when all available data indicate that the formation of the mineral was coincident with that of the mass of rock in which it occurs, the mineral can be classed as primary; in the latter case, when it has apparently originated through the alteration of primary compounds, it can be considered as secondary. The term secondary can also be applied in a restricted sense to such minerals as occur in veins, where the general character of the vein indicates that it has originated through the formation of fissures in existing strata and that the contents of the vein is of an age inferior to that of the mass of rock by which it is bounded.

In applying these considerations to the greater number of minerals which have up to this time been observed to contain radio-active constituents, it may be considered as fortunate that these minerals occur under conditions which would seem to render the task of assigning the individual species to one or the other of the above classes a relatively simple one.

The most prominent radio-active mineral, uraninite, more commonly known as pitchblende, occurs both as a primary constituent of granitic rocks and also as a constituent of metalliferous veins cutting geological formations of a relatively recent geological period. When occurring in a granitic rock the uraninite is frequently quite perfectly crystalline in form and the rock itself is of the type called pegmatite; the most noted localities furnishing specimens of this primary uraninite being southern Norway, particularly in the neighborhood of Moss, North Carolina, Llano Co., Texas, and Connecticut. Prominent localities where uraninite occurs as a constituent of metalliferous veins are Johanngeorgenstadt, Marienberg and Schneeberg in Saxony, Joachimsthal and Příbram in Bohemia, Cornwall in England, and Colorado and South Dakota in the United States.

The term secondary uraninite will be used in referring to the material from these latter localities.*

Among the radio-active minerals other than uraninite which occur as primary constituents of pegmatite may be mentioned thorite, samarskite, fergusonite, aeschynite, euxenite, monazite and the recently described† thorianite. Associated with, and obviously resulting from the alteration of, the primary minerals through the action of percolating waters and other agencies, are secondary minerals, the more prominent of which are gumunite, thorogummite, uranophane and autunite.

In considering the available data on the composition of radio-active minerals, with a view to discovering the ultimate disintegration products of the radio-elements, it is therefore necessary to give strict attention to the question of the primary or secondary origin of the individual specimens and the geological period at which they were formed. The nature of the associated minerals is also usually of considerable significance, since through them it is frequently possible to discover some clue to the conditions under which the mineral originated and some indication of the influences to which they have been subjected since they were first formed.

Lead.

In reviewing the various published analyses of minerals containing notable proportions of uranium, and particularly of those which are evidently of primary origin, one can not fail to be impressed by the frequent and almost invariable occurrence of lead as one of the other constituents. Out of a considerable number of analyses undertaken with the particular object of discovering whether or not lead was present, I have been unable to find a single specimen of a primary mineral containing over two per cent of uranium in which the presence of lead could not be demonstrated by the ordinary analytical methods. The same is moreover true of the secondary uranium minerals which have been examined, although in a single case, namely in a small specimen of uranophane from North Carolina, the proportion of lead was so low as to require the working up of a gram of material in order to conclusively demonstrate the presence of lead as a constituent.

Through a dawning appreciation of the significance of the persistent appearance of this element in uranium minerals, the writer was led to suggest in an earlier paper‡ that lead might prove to be one of the final, inactive disintegration products of uranium. All the data which have been obtained since that time point to the same conclusion.

* Hillebrand, this Journal, xl, 384 (1890).

† Dunstan and Blake, Proc. Roy. Soc. Lond. (A), lxxvi, 253 (1905).

‡ Phil. Mag. (6), ix, 613 (1905).

I have been particularly impressed by the information kindly supplied in a private communication by Mr. W. F. Hillebrand of the U. S. Geological Survey, a recognized authority on the analysis of uranium minerals, that so far as his experience goes he does not remember to have found uranium in any mineral without its being accompanied by lead, and he adds: "the association has often caused me thought."

Additional weight attaches to these experimental indications because of the theoretical considerations leading to a similar conclusion. It has been pointed out by Rutherford,* that if the alpha-ray particle consists of helium, since four alpha-ray products intervene between radium and the final, inactive substance radium-G, the indicated atomic weight of radium-G is sufficiently near to that of lead to be impressive. Thus one alpha particle is expelled by each of the atoms Ra, Ra-Em, Ra-A, Ra-C and Ra-F, making five particles in all. The loss of five alpha particles with an atomic weight of 4 from the atom of radium with an atomic weight of 225 would cause a reduction of this by $4 \times 5 = 20$ units, with the formation of a chemical element having an atomic weight of 205 or thereabouts. This is not far from the accepted atomic weight of lead, namely 206.9.

Thorium (Rare earths).

Another element which occurs quite commonly with uranium is thorium, and the common association of these two elements has been noted by Strutt and interpreted by him as indicating that thorium is possibly the parent of uranium.† Aside from the very doubtful hypothesis that the atomic weight of thorium is greater than that of uranium, his conclusions would seem open to serious objections. His statement that all thorium minerals contain readily detectable quantities of uranium, while some minerals containing notable quantities of uranium are comparatively free from thorium, is manifestly in accord with his experimental data, but it would appear that his thorium minerals containing uranium are all old minerals, while his uranium minerals containing no thorium are of relatively recent origin. If his theory is correct, the existence of very old minerals containing high percentages of uranium and no thorium should be possible, but that such minerals have been found is not indicated by any of the reliable analyses available. The experimental data offered by Strutt, as well as those to be derived from other sources, can all be much more consistently interpreted by the assumption that thorium is a disintegration product of uranium having a life considerably longer than that

* Silliman Lectures, Yale University, 1905. Not yet published.

† Proc. Roy. Soc. Lond. (A), lxxvi, 88 (1905).

of its parent and long as compared with the oldest of the known minerals. This hypothesis is supported by the circumstance noted by Strutt, that in general the minerals containing high proportions of thorium also contain a comparatively high proportion of helium, a point which will be referred to later in the course of this paper. Since the present knowledge of radio-active phenomena leads to the assumption that the average life of uranium is of the order of 2×10^9 years, while the average life of thorium is apparently in excess of that number, it seems scarcely reasonable to expect that minerals will be found which are sufficiently old for a state of equilibrium to have been reached between thorium and uranium. The production of a slowly changing disintegration product from a more rapidly changing parent is in no way contradictory to the disintegration theory, since a number of examples of this are at present recognized.* The common association of the other rare earths with thorium may indicate, as suggested by Strutt, that these are possible final products of the latter element.

Bismuth.

The occurrence of bismuth as a constituent of the more highly radio-active minerals is another significant indication of a possible end product. The proportion of bismuth which is present in the older radio-active minerals is, however, very small, so small indeed that its occurrence is but seldom detected in the ordinary course of analysis. It is only in treating considerable quantities of material for the extraction of polonium that the presence of bismuth becomes evident. This occurrence of bismuth in small quantities is suggestive of its formation from the disintegration, either of a parent having a relatively long life, or of one which is itself produced in only relatively small quantities. The former requirement would seem to be fairly well filled by thorium, in which case it is to be expected that in two minerals of equal age, the one containing the greater proportion of thorium would also contain the greater relative amount of bismuth. An opportunity has not yet been found for the experimental investigation of this question. The fact that the atomic weight of bismuth differs from the atomic weight of thorium by exactly 24 units, an even multiple of 4, is possibly significant.

Barium.

Another element which persistently appears as a minor constituent of uranium minerals is barium. Its production, if it is

* One example is the production of the active deposit from the thorium emanation, the parent with a half-value period of less than one minute, the product with a half-value period of eleven hours.

actually a disintegration product, is certainly slow, for only very small relative amounts of it are found in some comparatively old minerals. In primary minerals the amount of lead present is always greatly in excess of the barium, which occurs only in traces made evident in the separation of the radium from considerable quantities of material. As in the case of bismuth, the barium might be produced either from a slowly disintegrating parent or from a radio-active body existing only in comparatively small amounts in the radio-active system. Certain data, to be published later by the writer, have been obtained which seem to indicate that the amount of actinium in a radio-active mineral is dependent on the amount of uranium present, thus suggesting that uranium is the parent of actinium as well as of radium, but other results lead to the conclusion* that actinium is not a direct result in the same sense as is radium. The quantity of actinium produced in a radio-active mineral is apparently small as compared to the radium, and it may therefore be possible that the barium present is a final product of the actinium.

Hydrogen.

A point which has caused much speculation on the part of mineralogists is the apparent hydration of the greater number, if not all, of those minerals which are now known to contain radio-active constituents. That this state of affairs is in some way connected with the disintegration processes taking place in these compounds would not appear impossible, since the production of such an elementary substance as hydrogen as one of the products of the radio-active decay of the atoms of elements of high atomic weight is in fact suggested by much of the data on the nature of the expelled alpha particles.† It would seem possible that the difference in ionizing power, of the power of penetration, etc., shown by the alpha particles from certain of the radio-active types of material may perhaps be due to a difference in the mass of the projected particle, and that the occurrence of notable quantities of water in the primary radio-active minerals, which is otherwise most difficult to explain, may be considered as indicating that hydrogen is in fact one of the disintegration products, originating as an alpha-ray particle from one or more of the numerous radio-active substances which have already been identified. The origination of hydrogen in a mineral containing oxidized constituents would in all probability lead to the reduction of the more readily reducible of these with the consequent production of water.

* Rutherford and Boltwood, this Journal, xx, 56 (1905).

† Rutherford, "Radio-activity," p. 328 and elsewhere.

In the greater number of instances where water is found present in these minerals, it is quite impossible to explain how it could have penetrated into them from without, since their close-grained and impervious nature is impressively indicated by the very notable quantity of helium which they have retained. Moreover non-radio-active minerals which occur associated with the radio-active species, and which have been subjected to the same external influences, are often quite anhydrous, e. g., apatite, magnetite, etc. The mineral thorite has been called to the attention of the writer by Professor S. L. Penfield. This mineral frequently occurs in very perfect crystals, which however exhibit only the optical properties of an isotropic and amorphous compound. This species has been long regarded as having undergone alteration, but that the causes of the alteration existed within and not without the crystals is, I believe, a new and somewhat novel explanation.

It is a significant fact that results obtained* in the examination of certain radio-active minerals indicate that hydrogen occurs as one of the gaseous constituents of many of these compounds. A further interesting point bearing on this question is mentioned by Hillebrand,† who observed that when uraninite was mixed with sodium carbonate and fused in an atmosphere of carbon dioxide, the lead present was apparently entirely reduced and collected in globules. Mixtures of corresponding proportions of lead oxide (litharge) and U_2O_3 or UO_2 , when treated in an identical manner, showed no reduction of the litharge to metallic lead. This distinctive difference in behavior is strongly indicative of the presence of hydrogen as a constituent of uraninite.

Argon.

Results obtained by Ramsay and Travers‡ may further indicate that another of the disintegration products of radio-active substances is the inert gas argon. It is stated by these authors that most minerals which evolve helium also evolve argon in small quantity. It may not be impossible that some of the rayless changes which have been observed by Rutherford to take place in radio-active bodies, may be accompanied by the expulsion of alpha particles consisting of argon, which owing to their relatively high mass are projected at too low velocities to cause ionization of the surrounding gases and to permit

* Ramsay, Collie and Travers, Jour. Chem. Soc., Lond., lxvii, 684 (1895), state that hydrogen in varying quantities was evolved by yttrantalite, samarskite, hielmite, fergusonite, tantalite, monazite, xenotime, columbite, perofskite, euxenite, orthite, gadolinite and cerite. Also Ramsay, Proc. Roy. Soc. Lond., lix, 325 (1896).

† Bulletin of the U. S. Geological Survey, No. 78, p. 59 (1891).

‡ Proc. Roy. Soc. Lond., lii, 316 (1898).

their detection by the ordinary electrical methods. It has been pointed out by Rutherford* that the kinetic energy of certain alpha particles approaches quite closely to the critical value below which no ionization would be produced. It is moreover quite interesting that the assumption of a difference of atomic mass of 40 units between certain successive radio-active transformation products would greatly facilitate their assignment to vacant positions in the periodic system of the elements.

Composition of Uraninite.

The suggestions offered in the foregoing pages as to the possible nature of some of the disintegration products resulting from the process of radio-active change can be more clearly understood, and the basis of fact from which they have been derived can be more correctly appreciated, by a consideration of some of the results which have been obtained in the analysis of radio-active minerals.

The most accurate and reliable of the available data on the composition of uraninite have been published by Hillebrand.†

TABLE I.

Locality Number.	Glastonbury, Conn.				Branchville, Conn.				Colo.	N. Carolina.	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
UO ₂	22.08	23.35	22.22	26.48	23.08	13.27	21.54	14.00	25.26	50.83	44.11
UO ₃	59.13	58.01	59.31	57.43	59.93	72.25	64.72	70.99	58.51	39.31	46.36
Total Uranium	70%	70	70	72	72	74	75	74	72	77	77
PbO	3.14	3.24	3.07	3.26	3.08	4.35	4.34	4.35	0.70	4.20	4.53
ThO ₂	-----	-----	-----	9.79	-----	7.20 ²	6.93	6.52 ²	0.0	2.78	-----
Total rare earths	9.57	10.24	10.31	10.37	11.10	7.20	7.26	6.52	7.81	3.74	3.04
N ₂ ¹	-----	-----	-----	-----	2.41	-----	-----	2.63	0.15	0.37	-----
H ₂ O	0.97	-----	-----	0.61	0.43	0.68	0.67	0.68	1.96	1.21	-----
Sp. G.	9.12	9.05	-----	9.58	9.62	9.73	9.56	9.35	8.07	9.08	9.49

Various important details such as the general character and appearance of the different samples and the indication of alteration from external causes in a number of specimens will be found in Hillebrand's papers.

Blank spaces in the table signify that the indicated constituent was not determined.

¹ Hillebrand assumed that the inert gas present was nitrogen and the percentages of this element shown in the table are calculated on the basis of that assumption. By dividing these numbers by 7 a maximum value for the helium separated is obtained.

² ThO₂ + ZrO₂?

The results of his analyses are given in a condensed form in Table I.

* Phil. Mag., July (1905).

† Bulletin of the U. S. Geological Survey, No. 78, p. 43, 1891; this Journal, xl, 384 (1890); *ibid.*, xlii, 390 (1891).

Neglecting for the present the results under IX and XXII, which are types of secondary uraninites, it will noticed in an examination of the numbers given in Table I that—

1. In specimens from the same general locality, viz.: from Connecticut, from Norway and from North Carolina, a rough proportionality is shown between the content of uranium and the content of lead, rare earths, helium (nitrogen) and water. A still more striking relation appears to exist between the proportion of uranium in the form of the lower oxide, UO_2 , and the amount of helium (nitrogen). This was remarked by Hillebrand, who makes the following statement* in connection with the results obtained from the analysis of the first eighteen samples:

“Throughout the whole list of analyses in which nitrogen has been estimated the most striking features is the apparent relation between it and the UO_2 . This is especially marked in the table of Norwegian uraninites recalculated†, from which the rule might almost be formulated that, given either nitrogen or UO_2 , the other can be found by simple calculation. The same ratio is not found in the Connecticut varieties, but if the

TABLE I.

Norway.							Texas.	S. Carolina.	Canada.	Saxony.
XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI.	XXII.
30·63	25·86	22·04	32·00	35·54	42·71	26·81	44·17	---	41·06	59·80
46·13	50·74	43·03	43·88	43·38	24·18	44·18	20·89	---	34·67	22·33
66	66	57	65	68	56	61	55	71	65	68
9·04	10·06	8·58	9·46	9·44	10·54	10·95	10·08	3·58	11·27	6·39
6·00	8·48	---	8·98	6·68	---	4·15	6·39	1·65	6·41	0·0
7·62	9·03	8·43	10·48	8·09	13·42	13·87	19·19	10·25	10·49	0·0
1·17	1·28	1·08	1·03	1·08	---	1·24	0·54	---	0·86	0·02
0·74	0·73	0·74	0·77	0·79	1·23	---	1·48	---	1·47	3·17
8·89	9·14	8·32	8·96	8·93	7·50	---	8·29	---	---	6·89

Of the samples from Norway XII was from Annerød, XIII and XIV from Elvestad, XV from Skaartorp, XVI from Huggenåskilen, and XVII and XVIII from Arendal. Sample XIX was from Llano Co., Texas, XX from Marietta, South Carolina, XXI from Villeneuve, Canada, and XXII from Johannegeorgenstadt, Saxony.

determination of nitrogen in the Branchville mineral is to be depended on, the rule still holds that the higher the UO_2 , the higher likewise is the nitrogen. The Colorado and North Carolina minerals are exceptions, but it should be borne in mind that the former is amorphous like the Bohemian and possesses the further similarity of containing no thoria, although zirconia may take its place, and the North Carolina material is

* This Journal, xl, 391 (1890).

† Excluding the insoluble matter.

so much altered that its original condition is unknown." This generalization can apparently be extended to include lead also.

2. When the analyses of samples from the same actual locality are compared it will be evident that, in general,

a) The content of rare earths increases with the amount of lead present. This is most strikingly shown in the groups I-V, VI-VIII, XIII-XIV and XVII-XVIII. The simultaneous variation of thorium is also indicated somewhat imperfectly in those instances where this constituent was separately determined.

b) That in those specimens having the highest specific gravity (V and VIII) the proportion of helium compared with the lead present is greatest. It is in general to be expected that the denser and therefore less porous material would retain a greater proportion of the helium formed within it. The low proportion of gas compared with lead in X and XIX might well be due to the high emanating power of the former* and the greater porosity of the latter indicated by its low density. It is moreover interesting to note that those specimens (X, XIX, XXI) containing disproportionately large amounts of water contain a relatively low amount of helium compared with the lead present. It is possible that these minerals were sufficiently porous to permit the entrance of water from without while at the same time a part of the helium formed has escaped from within them.

It is evident that, in Table I, a lack of agreement exists between the proportion of lead and rare earths and the proportion of helium in the Connecticut material and the proportions of the corresponding constituents in the Norwegian samples. In the latter the amounts of lead and rare earths as compared with the gas present are much greater than in the former. This can be explained by assuming that the Norwegian minerals are considerably older than the American varieties, and that the Norwegian specimens examined by Hillebrand have in some manner lost a large part of their helium. The geological data available on the relative ages of the American and Norwegian occurrences, while not entirely in accord with the assumption of such a great difference in age, would not appear to be sufficiently definite to preclude such a possibility.

In considering the bearing of the results of the analyses of the two secondary uraninites, IX and XXII, on the general theories proposed in this paper, it is evident that the presence

* Phil. Mag. (6), ix, 609.

of the low proportion of lead and helium, and the practical absence of thorium in ix, is quite in accord with the geological indications that this material is of an age greatly inferior to that of the primary uraninites. In xxii the very notable amount of lead shown by the analysis would seem to offer no serious obstacle to the theory, since this material occurs intimately associated with the sulphide of lead and other similar minerals, and the massive and amorphous form in which it is found would indicate that the conditions under which it was originally deposited were not favorable to the separation of a pure uranium compound. The statement of Hillebrand* that nitrogen (helium) and the rare earths were practically absent in specimens of secondary uraninite from Pribram, Joachimsthal and Johanngeorgenstadt, which he examined, is also of interest in this connection. The experience of Debiernet† in separating actinium from a secondary uraninite of this character, is, however, indicative of the existence of small amounts of thorium in these minerals.

Other Radio-active Minerals.

In the table which follows (Table II) will be found some data compiled from various sources on the composition of a number of primary and secondary radio-active minerals.

As bearing on the topic under discussion it is interesting to note the following :—

1. The greatest proportion of helium with respect to the uranium and lead present has been observed in those primary minerals which have the lowest emanating power and the highest specific gravity, i. e., in the most compact and least porous minerals. Examples are furnished by thorianite, fergusonite, samarskite and monazite. (Of the varieties of thorite, much greater proportions of helium have been observed in the variety known as orangite, which has also the greatest density.)

2. Greater proportions of lead and helium with respect to uranium are found in those primary minerals which occur in the oldest geological formations. This point is well illustrated by thorianite, which is found in Ceylon in a geological formation which is probably of the Archean period.

3. The primary minerals containing the greatest proportion of thorium are in general the most hydrated.

In considering the secondary radio-active minerals certain probable conditions must be recognized. Where these minerals are formed by the alteration of primary minerals *in place*, namely, where the primary mineral is acted on by underground

* Bulletin U. S. Survey, No. 78, p. 72.

† Compt. rend., cxxx, 906 (1900).

TABLE II.
PRIMARY MINERALS.

Species.	Locality.	ThO ₂	UO ₂	PbO	H ₂ O	He	Reference.
Thorite, Hitterö, Norway	----	48.66	9.00 ¹	1.26	10.88	X ^a	Dana, p. 488
Mackintoshite, Llano Co., Tex.	----	45.30	22.40	3.74	4.31	X ^b	A ₁
Yttrialite, Llano Co., Tex.	----	10.85	1.64	0.80	0.32	X ^c	A ₁
Thorianite, Ceylon	----	78.86	.....²	2.59	X ^d	0.39%	A ₁
Samarskite	-----	-----	10-13%	-----	3-1%	X ^e	
" (?) Colorado	-----	3.64	4.02	0.72	1.58	?	Dana, p. 740
Annerödite, Anneröd, Nor.	----	2.37	16.28	2.40	8.19	?	Dana, p. 741
Euxenite	-----	-----	5-12%	0.92	4.71	?	Dana, p. 744
Hielmite, Falun, Sweden	----	?	2.34 ⁴	0.21	2.23	X ^e	Dana, p. 742
Polycrase, Slättakra, Nor.	----	3.51	18.45	0.92	4.71	X ^e	Dana, p. 745
Fergusonite, Llano Co., Tex.	----	0.83	7.05 ⁵	1.43	2.02	?	Dana, p. 730
"	----	?	3.81 ⁴	0.16	?	0.03	A ₁
Xenotime, Narestö, Sweden	----	2.43	3.48 ⁴	0.68	1.77	X ^e	Dana, p. 749
Monazite, North Carolina	----	5.00	0.40 ⁶	tr.	0.20	X ^e	

SECONDARY MINERALS.

		UO ₂					
Gummite, North Carolina	----- ⁷	75.20	5.57	10.54	?		Dana, p. 892
Thorogummite, Llano Co., Tex.	----	41.44	22.43	2.16	7.88	?	A ₁
Carnotite, Colorado	-----	0.0	52.25	0.25	3.06	0 ⁸	A ₁
Uranophane, North Carolina	----- ⁹	66.67	0.60	12.02	?		Dana, p. 699

¹ U₂O₃.² UO₂, 6.03 + UO₂, 9.07.³ Hofmann and Strauss (Berichte, xxxiii, 3126) state that they found both thorium and lead in samarskite and in euxenite.⁴ UO₃.⁵ UO₃ and UO₂.⁶ The composition of monazite given above is derived from experiments of the writer.⁷ Specimens of gummite from North Carolina analyzed by the writer have been found to contain from 2 to 8 per cent. of thorium.⁸ It is stated by Adams (this Journal, xix, 321 (1905)) that helium is absent from this mineral, which is to be expected since it is highly porous and of recent formation.⁹ Samples of this material have been examined by the writer in which no thorium could be detected.X^a Helium has been found in the variety of thorite known as orangite.X^b Hillebrand's experiments suggest the presence of helium in this mineral.X^c Including this species among the primary minerals is possibly open to objection. Hillebrand's experiments would seem to indicate that it contains from 1^{cc} to 2^{cc} of helium per gram.X^d The analyses of Dunstan and Blake (see Ref.) do not indicate the presence of water, but several tests made by the writer, on samples kindly supplied by Mr. Geo. F. Kunz, suggest the presence of water in quite notable quantities.X^e The occurrence of helium in samarskite, hielmite, polycrase, xenotime, monazite, orangite, and other radio-active minerals is described in papers by Ramsay, Collie and Travers (Jour. Chem. Soc. Lond., lxvii, 684) and Ramsay and Travers (Proc. Roy. Soc. Lond., lx, 442).A₁ W. F. Hillebrand, this Journal, xli, 101 (1893).A₂ Hillebrand, this Journal, xiii, 195 (1902).A₃ Dunstan and Blake, Proc. Roy. Soc. Lond. (A), lxxvi, 253 (1905).A₄ Ramsay and Travers, Proc. Roy. Soc. Lond., lii, 316 (1896).A₅ Hillebrand and Mackintosh, this Journal, xxxviii, 480 (1899).A₆ Hillebrand and Ransome, this Journal, x, 120 (1900).

waters, etc., with the removal of certain constituents and the substitution of others originally dissolved in the waters, the resulting hydrated residue will in some cases consist of a mixture of several different chemical compounds and its general composition will not correspond to any definite formula, but will depend on chance and the accidental local conditions. An excellent example of a secondary product of this character is afforded by the mineral known as gummite, which occurs as an alteration product of the North Carolina uraninites. Samples of this mineral from the Flat Rock mine have been examined by the writer, in which great variations in the proportions of lead, thorium and uranium present were observed in samples removed from different parts of the same comparatively small specimen. The mineral known as uranophane from the same locality shows corresponding variations in composition. Both these substances are amorphous in structure but very frequently occur with a crystalline form as pseudomorphs after the original uraninite. It is obvious that these facts must be considered in attempting to arrive at any conclusions from a chemical examination of these materials.

In other cases the percolating waters undoubtedly dissolve the more readily soluble components of the primary minerals and deposit them again as definite, crystalline compounds of a relatively high degree of purity. Examples of this sort are afforded by such minerals as torbernite $[\text{Cu}(\text{UO}_2)_2\text{P}_2\text{O}_7 \cdot 8\text{H}_2\text{O}]$, autunite $[\text{Ca}(\text{UO}_2)_2\text{P}_2\text{O}_7 \cdot 8\text{H}_2\text{O}]$, uranocircite $[\text{Ba}(\text{UO}_2)_2\text{P}_2\text{O}_7 \cdot 8\text{H}_2\text{O}]$, zeunerite $[\text{Cu}(\text{UO}_2)_2\text{As}_2\text{O}_7 \cdot 8\text{H}_2\text{O}]$, uranosphaerite $[(\text{BiO})_2\text{U}_2\text{O}_7 \cdot 3\text{H}_2\text{O}]$, and a considerable number of others. The examination of minerals of this character will probably afford data of considerable value on the nature of the ultimate disintegration products of uranium.

The mineral mackintoshite is quite possibly of secondary origin, but owing to some doubt in the matter it has been placed among the primary minerals. It may represent a variety of thorite, containing originally a considerable proportion of uranium, which has undergone alteration owing to the radio-active processes which have taken place within it. The evidence is strongly in favor of the view that the thorogummite has been formed from the alteration of the mackintoshite through external causes.

Any definite conclusions at present as to the formation of carnotite are quite impossible. Its composition and occurrence are both so unique that little or no analogy with other known uranium compounds can be detected. It seems highly probable, however, that its age is not relatively very great and its general composition, *e. g.* the low amount of lead present and the practical absence of thorium and helium, is quite in accord with such a conclusion.

An interesting radio-active mineral has been described by Danne.* This substance is stated to be a phosphate of lead, or pyromorphite, containing quantities of radium equivalent to about 6 per cent of uranium. It is asserted, however, that no uranium is present in the mineral, although considerable deposits of uranium minerals are known to exist at no very great distance in the same region where it occurs. According to Danne, the pyromorphite is found in fissures through which underground waters containing radium salts are constantly percolating, and he suggests that the radium contained in the mineral is derived from the water. It might also be conjectured that the lead of the mineral has resulted from the disintegration of radium, the radium itself having been formed from the disintegration of uranium in the neighboring deposits.

Occurrence of Minerals.

It would seem possible that some general data on the disintegration products of radio-active substances might be derived from the study of the conditions under which the radio-active minerals occur in nature. The following suggestions may perhaps be of interest in this connection. The primary minerals found in the pegmatitic dikes include uraninite, thorite, fergusonite, aeschenite, euxenite, columbite and monazite, all of which, with the exception of columbite,† probably contain thorium in greater or smaller proportions. The theory generally accepted by geologists is that the pegmatites were formed under conditions of so-called hydro-igneous fusion, involving high temperatures and the presence of considerable water vapor which was prevented from escaping by the high pressure due to incumbent masses of rock of great thickness. Assuming the prior existence of considerable deposits of uranium compounds at great depths, it would appear probable that in an upheaval of deep-lying material, with the intrusion of the plastic magma into the upper layers from below, the conditions would be favorable to the separation of the various constituents of the already partially disintegrated uranium with the production of new minerals representing new combinations of the various elements present. Thus some of the uranium might separate out as the oxide (uraninite), either quite free from other elements or with admixtures of other isomorphous oxides (thorium oxides and other rare earth oxides), while the thorium might be greatly concentrated in the form of such minerals as thorite and thorianite, containing mixtures of variable propor-

* Compt. rend., cxl, 241 (1905).

† The very common association of radio-active elements with niobium, tantalum, etc., in minerals is possibly significant of some ultimate relation between them.

tions of uranium and the rare earths. Others of the rare earths present might be themselves concentrated to form such minerals as allanite and gadolinite, compounds containing but relatively small proportions of the radio-elements.

When uraninite is found in metalliferous veins the general indications point to its transportation hither from greater depths by thermal waters and its deposition at a temperature considerably lower than that existing in the plastic pegmatite. The association of the secondary uraninites with the sulphides of iron, copper, lead, bismuth and other metals is indicative of conditions of deposit unfavorable to the simultaneous production of rare earth minerals, which have never been observed to occur under similar conditions in any locality.

The mode of occurrence of radio-active minerals would therefore appear to offer certain valuable data on the processes taking place in the radio-elements and the products formed by their disintegration.

Origin of Elements.

If it can be ultimately demonstrated that lead, bismuth, barium, hydrogen and argon, or any one of them, actually result from the disintegration of uranium, an interesting question which naturally arises will be: Have the quantities of these chemical elements already existing been produced wholly in the same manner? Any discussion of this problem at the present time would certainly be premature, but the time may not be very far remote when this question will deserve serious consideration.

Summary.

Various data have been presented which are interpreted as indicating that the ultimate disintegration products of the radio-elements may include lead, bismuth, barium, the rare earths, hydrogen and argon.

The writer is fully conscious of the meagerness of the data upon which the hypothesis of the production of these substances is founded, but the suggestions are made in the hope that the attention of other investigators may be directed to the possibilities offered by a careful study of the composition and occurrence of the radio-active minerals, and that their interest may be sufficiently awakened to induce them to independently undertake the experimental investigation of the theories which have been suggested.

139 Orange St., New Haven, Conn.

August 16, 1905.

ART. XXIX.—*The Use of the Rotating Cathode for the Estimation of Cadmium taken as the Sulphate*; by CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxix.]

In a recent paper from this laboratory* has been described the application of the rotating cathode to the rapid estimation of copper, silver and nickel; and, in a later paper,† its fitness for the estimation of cadmium as well as several other metals has been shown. The object of the present investigation has been to more thoroughly study the conditions under which cadmium may be estimated by this means. The apparatus used was that described in the previous papers. Since it had already been shown‡ that cadmium taken in the form of the sulphate can be estimated by deposition of a solution slightly acidulated with sulphuric acid, this formed the natural point of departure.

I. *In Solutions containing Sulphuric Acid.*

A solution of cadmium sulphate was prepared, containing approximately 16.6 grams of the salt to the liter of water. Portions of this solution were carefully measured from a burette, diluted to the desired volume, a few drops of dilute sulphuric acid (1:4) added, the proper connections made and the electrolysis conducted as previously described. The following were the results obtained upon two different solutions:

SOLUTION A.							
No. of Exp.	Sol. taken. cm ³ .	H ₂ SO ₄ . (1:4) drops.	Time. min.	Cur't read. = amp.	N.D. ₁₀₀ amp.	E.M.F. approx. volts.	Cd. found grm.
1.	15	5	18	0.4–1.0	1.2–3.0	8	0.1111
2.	15	5	10	0.4–0.5	1.2–1.5	8	0.1090
3.	15	5	16	0.4–0.9	1.2–2.7	8	0.1115
4.	15	7	35	0.5–1.0	1.5–3.0	8	0.1117
5.	15	12	25	1.0–1.5	3.0–4.5	8	0.1115
6.	15	10	35	1.0–1.5	3.0–4.5	8	0.1120
7.	15	18	30	1.5–2.0	4.5–6.0	8	0.1119
8.	15	15	25	1.5–2.0	4.5–6.0	8	0.1117
9.	30	Indef.	15	3.0–4.0	9.0–12.0	8	0.2235
10.	20	12	35	2.0–3.0	6.0–9.0	8	0.1491
11.	15	Indef.	60	2.0	6.0	8	0.1120

In experiments numbered 1 to 4, the liquid at the end of the period indicated showed traces of cadmium remaining, but in the seven experiments following these the cadmium was all deposited upon the cathode in a satisfactory condition. These

* Gooch and Medway, this Journal [4], 320 (1903).

† Medway, *ibid.* [4], xviii, 56 (1904).

‡ Loc. cit.

results were therefore taken as indicating the standard of the solution used, the mean of the series showing the presence of 0.007454 grm. of cadmium in each cubic centimeter of the solution.

In a second solution which it became necessary to standardize the following results were obtained :

SOLUTION B.						
No. of Exp.	Sol. taken. cm.	Time. min.	Cur't read. = amp.	N.D. ₁₀₀ amp.	E.M.F. vts.	Cd. found. grm.
1.	20	27	1.0-1.5	3.0- 4.5	7.9	0.0816
2.	25	30	2.0-3.0	6.0- 9.0	7.9	0.1018
3.	25	55	2.5-4.0	7.5-12.0	7.6	0.1019
4.	30	25	2.0-2.5	6.0- 7.5	12.0	0.1224
5.	30	20	1.0	3.0	7.8	0.1223
6.	30	10	1.5-2.5	4.5- 7.5	7.8	0.1226

The mean of these six experiments gives a value of 0.10194 grm. of cadmium for every 25^{cm}³ of the solution, or 0.0040776 grm. for each cubic centimeter. This value was taken as the standard whenever this solution was used.

One point which was not mentioned in the former paper* on the estimation of cadmium by this method, but which is of much importance, is that of dilution. The earlier experiments in this work were performed at a dilution of from 65^{cm}³ to 75^{cm}³. Much trouble was experienced, however, at this dilution; for the last traces of the metal were driven from the solution only with extreme difficulty and with much loss of time, as may be noted by comparing the time interval of most of the experiments with the shorter interval of the last two experiments of the second series, where the dilution was 45 to 50^{cm}³. Moreover it was found advisable, in order to avoid mechanical loss, to deposit not more than 0.2 grm. to 0.25 grm. of the metal upon the cathode, while even smaller quantities are to be preferred. The current density must also be kept within the limits indicated; for otherwise a spongy deposit may result. Cadmium seems to be especially liable to the formation of these spongy, unweighable deposits, and the greatest difficulties experienced in this investigation have come from this behavior of the metal.

The best condition, therefore, may be briefly summarized as follows: Cadmium sulphate, equivalent to not more than 0.2^{cm} to 0.25 grm. of the metal, is dissolved in 45^{cm}³ to 50^{cm}³ of water; ten to fifteen drops of dilute sulphuric acid are added; and the proper connections made and the solution subjected to electrolysis as described, fifteen minutes being sufficient time for the complete deposition of the metal upon the cathode. It

* Loc. cit.

is not necessary to heat the liquid, as the passage of such large currents soon heats it sufficiently. When electrolysis is complete, the excess of sulphuric acid may be destroyed with a slight excess of ammonia water, the current broken, and the cathode removed, thoroughly rinsed with water and alcohol, and dried by waving over a free flame. If the deposit is not spongy the drying is a matter of only a few moments, and there is no danger of oxidizing the metallic deposit. If it is preferred, the current may be reduced by interposed resistance, the rotation stopped, and the liquid readily siphoned without danger of injuring the metallic coating.

II. *In Solutions containing Acetates.*

The next method to be studied in its application to the rotating cathode was the use of solutions containing acetates, as recommended by Edgar F. Smith. Originally, Smith used a solution obtained by dissolving cadmium oxide in acetic acid* but later found that the electrolysis proceeded equally well in solutions containing the nitrate, chloride or sulphate of cadmium with an excess of sodium acetate.† In the study of the application of this method to the estimation of cadmium, taken as the sulphate, upon the rotating cathode, two methods of proceeding were followed, both of which had been previously used by Exner‡ in his work upon the rotating anode. In series A, of the experiments following, measured amounts of cadmium sulphate solution were run off from a burette, the indicated amount of sodium acetate was added in solution, a small amount of potassium sulphate was added to increase the conductivity of the solution, the whole diluted to the desired volume and electrolysis conducted as with the solution containing sulphuric acid. In series B, the cadmium in the measured solution was precipitated as the hydroxide with a sodium hydrate solution, the precipitate dissolved in a very slight excess of acetic acid, potassium sulphate added as before, and the solution subjected to electrolysis.

SERIES A.										
No.	Cd. taken.	NaOC ₂ H ₃ O.	K ₂ SO ₄ .	Cur't		N.D. ₁₀₀ .	E.M.F.	Time.	Cd. fd.	Error.
	grm.			grm.	grm.					
1.	0.1864	1.5	0.5	2.0		6.0	8.0	.	(S)	----
2.	0.1491	2.0	1.0	1.5		4.5	8.0	15	(H)	----
3.	0.1118	0.5	1.0	1.0		3.0	8.0	20	0.1121	+ 0.0003
4.	0.1491	1.5	0.5	0.9		2.7	8.0	15	0.1494	+ 0.0005
5.	0.1491	1.5	0.5	0.9		2.7	8.0	15	0.1496	+ 0.0005
6.	0.1223	1.5	0.5	0.75		2.25	7.5	20	0.1237	+ 0.0014

* Ber., xi, 2048 (1878).

† Am. Ch. J., ii, 41 (1880).

‡ J. Am. Ch. Soc., xxv, 896 (1903).

§ Did not weigh, as precipitate was non-adherent. Current too high for quantity of cadmium present.

| Deposits spongy and blistered. Too much electrolyte present.

SERIES B.

No.	Cd. taken. gram.	NaOH. gram.	K ₂ SO ₄ . gram.	Cur't = amp.	N.D. ₁₀₀ amp.	E.M.F. vts.	Time. min.	Cd. found. gram.	Error. gram.
1.	0.1491	excess	0.5	1.25	3.75	8.0	10	0.1496	+0.0005
2.	0.1491	0.2	0.5	0.8	2.4	8.0	15	0.1491	±0.0000
3.	0.1491	0.2	0.5	0.8	2.4	8.0	15	0.1493	+0.0002
4.	0.1223	0.5	0.2	1.0	3.0	12.0	20	0.1223	±0.0000
5.	0.1223	0.5	0.2	1.0	3.0	12.0	20	0.1223	±0.0000
6.	0.1223	0.2	0.5	1.25	3.75	7.5	10	0.1227	+0.0004

In both series the volume of the solution was about 60^{cm}³ to 65^{cm}³. The sixth experiment in each series will indicate the result when the greater concentration of 45^{cm}³ to 50^{cm}³ was tried. In these cases the precipitate showed a tendency to sponginess, which was more noticeable in series A. At the greater dilution, the deposition of the cadmium proceeds rapidly and satisfactorily; the deposit is rather crystalline, fairly compact, and easily washed, so that the method forms one of the very best where the cadmium is taken in the form of the sulphate: the chloride and nitrate behave differently and will be treated later. The second modification seemed to give deposits more satisfactory than the first. Certain cautions, however, are to be observed. Not more than 0.1500 gram. may safely be estimated; the normal current density should not exceed 3.0 amperes if a spongy deposit is to be avoided; and, for the same reason, a large excess of electrolytes is to be avoided.

III. In Solutions containing Cyanides.

The deposition of cadmium from a solution of the double cyanide has always been very satisfactory, and the results with the rotating cathode were in complete accordance with previous work on this method. The range of conditions of current and quantity of electrolyte is broad, the deposit is a beautiful silvery plate, so compact as to be rubbed off only with difficulty, which dries very quickly; and although the complete deposition of the metal is not so rapid as it is from solutions containing sulphates or acetates, it is sufficiently rapid. Care should be taken to avoid foaming of the solution, as this retards somewhat the deposition of the final traces of cadmium. Generally, a volume of 65^{cm}³ to 70^{cm}³ was found most satisfactory. The solution was run off into a beaker of convenient size, the cadmium precipitated with sodium hydroxide, and the precipitate redissolved in potassium cyanide. The following results were obtained:

No.	Cd. taken. gram.	NaOH. gram.	KCN. gram.	Cur't read = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. found. gram.	Error. gram.
1.	0.1491	1.5	0.5	2.5	7.5	8	35	0.1498	+0.0007
2.	0.1491	1.0	0.5	2.5-4.5	7.5-13.5	8	30	0.1490	-0.0001
3.	0.1223	1.5	1.0	2.5	7.5	8	35	0.1225	+0.0002

IV. *In Solutions containing Pyrophosphates.*

Brand* has recommended the use of a solution containing sodium pyrophosphate for the electrolytic estimation of metals, among others, cadmium: and the fitness of this solution for use with the rotating cathode was now studied. In each case the cadmium was precipitated with the indicated amount of sodium pyrophosphate, the precipitate dissolved in an excess of ammonium hydroxide (series A), phosphoric acid of 1.7 specific gravity (series B), sulphuric acid (series C), or hydrochloric acid (series D), and subjected to the action of the current. The volume of the solution was 60cm³.

While fairly accurate results may be obtained, the method is neither so accurate as those previously described, nor are the conditions so flexible. Particular care must be used to avoid too large a current, as a spongy deposit may result. The following were the results obtained:

SERIES A.									
No.	Cd. taken. gram.	Na ₂ P ₂ O ₇ . gram.	NH ₄ OH.	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. fd. gram.	Error. gram.
1.	0.1491	0.5	15cm ³ (1:4)	1.0-1.5	3.0-4.5	8	15	0.1498	+0.0007
2.	0.1491	0.5	excess.	0.4	1.2	8	15	0.1489	-0.0002
3.	0.1864	0.5	15cm ³ (conc.)	0.7	2.1	8	15	0.1869	+0.0005

SERIES B.									
			H ₃ PO ₄ (1.7 sp. gr.)						
4.	0.1491	1.0	1.0cm ³ .	1.0	3.0	8	30	0.1496	+0.0005
5.	0.1864	1.0	1.0 "	1.0-1.5	3.0-4.5	8	30	0.1857	-0.0007
6.	0.1491	1.0	1.0 "	1.0	3.0	8	30	0.1493	+0.0002

SERIES C.									
			H ₂ SO ₄ .						
7.	0.1491	1.0	2cm ³ (1:4)	2.0-2.5	2.0-7.5	8	30	0.1501	+0.0010
8.	0.1864	0.5	excess.	1.0-2.0	3.0-6.0	8	35	0.1862	-0.0002

SERIES D.									
			HCl.						
9.	0.1491	0.5	slt. excess.	1.0	3.0	8	37	0.1499	+0.0008
10.	0.1491	0.5	" "	1.0	3.0	8	36	0.1486	-0.0005

* Z. anal. Ch. xxviii, 581 (1889).

In Nos. 1 and 3 a small amount of dilute sulphuric acid was added to increase the conductivity of the solution, but the time was not reduced thereby, while the resulting deposit was slightly spongy.

In No. 5 the cadmium was not quite all precipitated.

In No. 7 the precipitate was spongy.

V. In Solutions containing Phosphates.

The use of a solution containing the orthophosphates dissolved in phosphoric acid has been recommended by Smith*, and this solution was next tried. The following results will show the scope of the modifications tried :

No.	Cd. taken. gram.	HNA ₂ PO ₄ . gram.	H ₂ PO ₄ . (1:7) cm.	Total vol. cm.	Cur't.= amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. fd. gram.	Error. gram.
1.	0.1491	0.5	1.0	75	1.0-1.2	3.0- 3.6	8	20	0.1477	-0.0014
2.	0.1491	0.5	5.0	75	2.0-2.5	6.0- 7.5	8	23	0.1496	+0.0005
3.	0.1491	0.5	5.0	75	2.0-1.5	6.0- 4.5	8	30	0.1508	+0.0017
4.	0.1491	0.5	3.0	75	2.5	7.5	12	25	0.1502	+0.0011
5.	0.1491	0.5	4.0	75	2.5	7.5	8	25	0.1485	-0.0006
6.	0.1491	9.5	2.0	75	2.5	7.5	12	35	0.1501	+0.0010
7.	0.1864	0.25	2.0	75	2.0-3.0	6.0- 9.0	12	40	0.1861	-0.0003
8.	0.1491	0.3	1.5	75	3.5	10.5	12	30	0.1502	+0.0011
9.	0.1019	0.25	5.0	75	2.5-3.0	7.5-9.0	7.8	30	0.1024	+0.0005
10.	0.1019	0.25	5.0	75	3.0-3.5	9.0-10.5	7.8	30	0.1027	+0.0008
11.	0.1223	0.2	5.0	75	3.0-3.5	9.0-10.5	7.8	40	0.1221	-0.0002

No. 1.—Not all out. No. 2.—Slight yellow color with H₂S.

No. 3.—Slight yellow with H₂S. No. 4.—Spongy. No. 5.—Not all out. No. 6.—Spongy. No. 10.—Spongy. No. 11.—Slight test with H₂S.

From this series of experiments it may be seen that the method may be made to give fair results if the following conditions are closely adhered to: for a total volume of 75^{cm}3, the cadmium is precipitated with 0.25 gram. of hydrogen disodic phosphate, 5^{cm}3 of phosphoric acid (sp. gr. = 1.7) added, and the solution electrolyzed with a current of about 8 volts potential. If the normal current density does not exceed 9 amperes, the deposit will be fair, and complete in about 30 minutes.

VI. In Solutions containing Oxalates.

Much work was expended upon the oxalate method, but in spite of this, a satisfactory deposit could not be obtained. When ammonium oxalate was present, even in small amounts, the deposit was very spongy: while the use of sodium oxalate alone, when carried down even to the smallest excess possible

*Am. Ch. J., xii, 329 (1890).

to give a soluble double oxalate, gave results much too high. The dissolving of the precipitated oxalates in various reagents furnished no solution to the problem.

The results in the following table will show the scope of the work done:

No.	Cd. tkn. grm.	Am. oxalate. grm.	Pot. oxalate. grm.	Solvent.	Cur't = amp.	N. D., amp.	E. M. F. volts.	Time. min.	Cd. fd. grm.	Err. grm.
1.	0.1491	excess	none	none	3.0	9.0	12	?	0.1558	+0.007
2.	0.1491	slt. excess	none	"	2.5	7.5	12	30	0.1506	+0.005
3.	0.1491	2.0	0.5	"	2.0-2.5	6.0-7.5	8	25	0.1531	+0.000
4.	0.1491	none	0.5	{ H ₂ SO ₄ 15 dps.	2.5	7.5	8	30	0.1476	-0.004
5.	0.1491	"	8.0	none	2.0	6.0	6.2	20	0.1507	+0.006
6.	0.1118	4.0	none	"	1.5	4.5	6.1	20	0.1272	+0.004
7.	?	none	5.0	{ NH ₄ OH, few cm.	2.0-3.5	6.0-10.5	6-8	18	?	?
8.	0.1118	"	5.0	none	1.5	4.5	6.0	15	0.1129	+0.001
9.	0.1019	"	4.0	"	2.0-3.0	6.0-9.0	8	20	0.0995	-0.004
10.	0.1019	"	6.0	"	0.5-1.5	1.5-4.5	4-6	35	0.0982	-0.007
11.	0.1019	"	5.0	"	1.0	3.0	5.5	55	0.1033	+0.004
12.	0.1019	"	7.0	"	0.5	1.5	4	55	0.1030	+0.001
13.	0.1223	2.0	8.0	"	0.1-0.15	0.3-0.45	4	60	0.1236	+0.002
14.	0.1223	2.0	8.0	"	0.02-0.10	0.06-0.3	4	76	0.1229	+0.000
15.	0.1223	{ KOH 1 grm.	{ H ₂ SO ₄ dil. 10 ^{cm}	{ oxalic acid 5 grm.	3.0	9.0	8	40	0.0876	-0.004
16.	0.1223	{ KOH 0.25 grm.	----	{ oxalic acid 10 grm.	----	----	----	----	----	----
17.	0.1019	----	----	{ oxalic acid 1 grm.	1-2	3-6	8	35	0.1033	+0.004
18.	0.1019	----	----	{ oxalic acid 3.5 grm.	3	9	8	60	0.1018	-0.001

Of these, numbers 1, 2, 3, 6, 8, 9, 14, 15, 17, and 18 gave very spongy precipitates, while No. 7 was so spongy that it could not be satisfactorily dried, and so was not weighed. In experiments numbered 4, 9, 10, 14, 15, and 18 the cadmium was not all precipitated in the time allowed. In No. 10, also the precipitate was non-adherent. In No. 16, the oxalate was precipitated and was not broken up by the current.

VII. *In Solutions containing Urea, etc.*

Balachowsky*, obtained good results by the electrolysis of solutions containing, in addition to cadmium salts, urea and various aldehydes. These solutions were found to offer no difficulties with the rotating cathode, when cadmium sulphate is taken, as may be seen from the following results. The deposits were gray, compact, and quickly dried. The solution was diluted to about 60^{cm}³ or 70^{cm}³, and the best current potential was found to be that given by six storage cells connected in series—approximately 11.8 volts.

* *Compt. rend.*, cxxxi, 385 (1900).

SERIES A.—Urea, 8 grms.

No.	Cd. taken. gram.	Cur't = amp.	N.D. ₁₀₀ . amp.	Time. min.	Cd. found. gram.	Error. gram.
1.	0.1019	0.25-0.5	0.75-1.5	35	0.1018	-0.0001
2.	0.1223	0.2	0.6	35	0.1223	±0.0000
3.	0.1223	0.25-0.5	0.75-1.5	30	0.1230	+0.0007

SERIES B.—Formalin, 2^{cm}³.

1.	0.1019	0.1 -1.0	0.3 -3.0	30	0.1018	-0.0001
2.	0.1223	0.2 -1.0	0.6 -3.0	30	0.1224	+0.0001
3.	0.1223	0.2 -1.0	0.6 -3.0	30	0.1225	+0.0002

SERIES C.—Acetaldehyde, 2^{cm}³.

1.	0.1019	0.1 -0.8	0.3 -2.4	35	0.1022	+0.0003
2.	0.1223	0.1 -0.8	0.3 -2.4	30	0.1228	+0.0005
3.	0.1223	0.1 -0.8	0.3 -2.4	30	0.1222	-0.0001

Since the conductivity of the solutions containing urea and the aldehydes is comparatively low, the effect of adding electrolytes was tried. The rate of deposition was very much increased, but the precipitated metal showed such tendency toward sponginess that this procedure is not to be highly recommended. The following were the tests tried :

SERIES A.—Urea, 8 grms.; Time, 20 min.; E.M.F., 7.8 volts; Current read, 0.5 amperes; N.D.₁₀₀, 1.5 amperes.

No.	Cd. taken. gram.	Electrolyte.	Cd. found. gram.	Error. gram.	Notes.
1.	0.1019	K ₂ SO ₄ , 0.5 gram.	0.1031	+0.0022	spongy.
2.	0.1019	same	0.1031	+0.0022	"
3.	0.1019	{ H ₂ SO ₄ (1:4) 5 drps.	0.1023	+0.0004	good ppt.
4.	0.1019	same as 3	0.1027	+0.0008	slt. spgy
5.	0.1019	{ H ₂ SO ₄ (1:4) 8 drps.	0.1027	+0.0008	" "

SERIES B.—Formaldehyde (formalin), 2.5^{cm}³; Time, 20 min.; E.M.F. 7.9 volts. Current started at 0.5 ampere and rose to 1.0 ampere at the end of the process (N.D.₁₀₀ = 1.5-3.0 amperes.) In each case the precipitate was good. Ten drops of dilute sulphuric acid were added to increase the conductivity of the solution.

No.	Cd. taken. gram.	Cd. found. gram.	Error. gram.
1.	0.1019	0.1020	+0.0001
2.	0.1019	0.1019	±0.0000

VIII. In Solutions containing Formates.

The use of the solutions containing potassium formate and a slight excess of formic acid has been recommended,* but I

* Warwick, Z. anorg. Ch., i, 285 (1892); Avery and Dales, J. Am. Ch. Soc., xix, 380 (1897).

was unable to adapt this method to the rotating cathode. When potassium formate was present in even the smallest amounts the precipitate was spongy, and non-adherent. From solutions containing formic acid alone, however, the metal is deposited in a satisfactory form, but only after long passage of the current. The following results will show the limit of applicability of the process, experiments numbered 8 and 9 seeming to represent the most desirable conditions:

No.	Cd. tkn. grm.	KCHO ₂ sat. sol. cm ³ .	HOCHO.	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0.1019	2	--	1.0 -2.0	3-6	8	17	} Not weighed ; ppt. blistered and dropped off.	
2.	0.1223	0.5	--	0.4	1.2	8	--		
3.	0.1223	0.5	--	0.4	1.2	8	--		
4.	0.1223	0.5	--	0.4	1.2	8	--		
5.	0.1223	--	15 dps.	0.25-0.8	0.75-2.4	12	25	0.1228	+0.0005
6.	0.1223	--	15 "	0.25-0.8	0.75-2.4	8	25	0.1212	-0.0010
7.	0.1223	--	21 "	0.5 -1.5	1.5 -4.5	12-16	35	0.1202	-0.0021
8.	0.1019	--	1.5 cm ³	0.5 -1.0	1.5 -3.0	12	60	0.1022	+0.0003
9.	0.1223	--	1.5 "	0.4 -1.0	1.2 -3.0	12	55	0.1218	-0.0005

In the experiments numbered 5, 6 and 7 the cadmium was not all precipitated in the time indicated, as was shown by testing the solution with hydrogen sulphide.

IX. *In Solutions containing Tartrates.*

Solutions containing ammonium tartrate were also tried, but failed to give satisfactory deposits, the deposit in each case being spongy. If the solution contain only tartaric acid, however, in place of its salts, fairly satisfactory results may be obtained, as shown by the following table:

No.	Cd. tkn. grm.	Tartaric acid. grm.	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0.1223	3	0.5-1.0	1.5-3.0	8	20	0.1212	-0.0011
2.	0.1223	2	0.5	1.5	8	30	0.1216	-0.0007
3.	0.1223	2	0.5	1.5	8	50	0.1215	-0.0008
4.	0.1019	3	1.5	4.5	11.8	18	0.1022	+0.0003

Tests with hydrogen sulphide showed that the cadmium was not all precipitated in the tests numbered 1, 2 and 3, which were performed at a dilution of 70 cm³; experiment 4 was performed at a dilution of 50 cm³. It will be noted that, as in the sulphate process, the last traces of cadmium are thrown out of the higher state of dilution only with extreme difficulty.

ART. XXX.—*The Crystallization of Luzonite ; and other Crystallographic Studies ;* by ALFRED J. MOSES.1. *The Crystallization of Luzonite.*

THE reddish bronze, fine-grained variety of Cu_3AsS_4 , which is found in the copper veins of Mancayan, Luzon Island in the Phillipines, has been generally accepted as dimorphous with enargite, but the minute crystals, "tiny individuals of unrecognizable form,"* observed in the cavities growing from the granular mass have not been measured but rather referred to as "indistinct, uneven, striated crystals not rhombic but monoclinic or even triclinic."†

Recently Mr. Maurice Goodman, senior field assistant in the Bureau of Mines, Manila, collected a number of luzonite specimens showing these crystals in cavities, from which I selected and measured the crystals here described.

Crystals No. 1 and No. 2.—A mass of typical luzonite, free from all visible columnar blackish enargite, showed a number of cavities the walls of which were crystallized ; that is, little detached fragments of the walls under the microscope were seen to be faceted by minute crystals which projected very slightly and the faces of which could be traced down until they merged in the bronze-colored mass. They were not implanted on or enclosed in the mass, but distinctly suggested that the mass on solidifying formed little facets such as form on the cooling of a fused mass of pyromorphite. It is curious and probably of genetic significance, that the terminal planes of these crystals are decidedly lighter in color and of less brilliant luster than the side planes, the latter suggesting the dark gray of enargite or stibnite and the former a reddish steel-gray not very different from the tint of the massive luzonite. In more than one instance in which a fracture extended across a crystal into the massive material it was impossible to see any difference in the color or character of the surfaces.

Two little crystals were mounted for measurement. No. 1, shown in fig. 1, was only $\frac{1}{8}$ to $\frac{1}{2}^{\text{mm}}$ in any direction, but was attached to a fragment of the mass from which it had developed. Signals were obtained in the two-circle goniometer from seven faces but were a little blurred. Crystal No. 2, shown in fig. 2, was the largest crystal I observed as a cavity wall facet, and its terminal face was approximately a rhomb of $1\frac{1}{2} \times \frac{3}{4}^{\text{mm}}$. It also yielded signals from seven faces and a series of signals from a curved triangular surface.

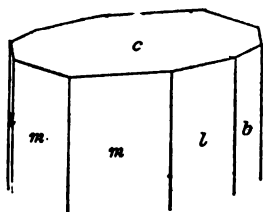
In both crystals the terminal faces were reddish steel-gray and the vertical faces dark gray. Taking the terminal faces

* Weisbach, *Tscher. Min. Mitth.*, 1874, 257.

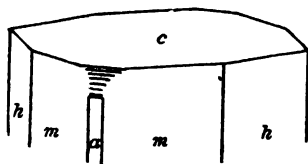
† Frenzel, *ibid.*, 1877, 303.

as $c = 001$, the consideration of the angles in the vertical zone suggested an orientation for comparison with the common forms of enargite as follows:

1



2



Enargite Form.	Crystal No. 1.		Crystal No. 2.	
	Face.	Signal. Measured ϕ .	Face.	Signal. Measured ϕ .
$c=001$	1	Fair	1	Fair
$m=110$	5	Double $48^\circ 57'$	2	Double $49^\circ 02'$
	6	" $48^\circ 58'$	5	Fair $48^\circ 44'$
	7	Blurred $48^\circ 30'$	-	-
$h=120$	-	-	3	Faint $31^\circ 44'$
$l=130$	2	Fair $20^\circ 22'$	-	-
	4	Double $19^\circ 17'$	-	-
$b=010$	3	" $0^\circ 5'$	-	-
$a=100$	-	-	7	Double $89^\circ 46'$
hol	-	-	curved Series	$90^\circ 0'$

The comparison of the averaged angles is:

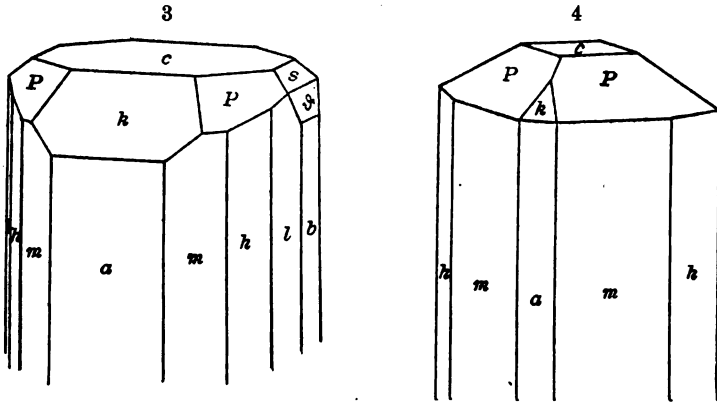
Enargite ϕ .	Crystal No. 1 ϕ .	Crystal No. 2 ϕ .
$m=48^\circ 59' 47''$	$48^\circ 48'$	$48^\circ 56'$
$h=29^\circ 54' 13''$	-	$31^\circ 44'$
$l=20^\circ 58' 38''$	$20^\circ 22'$	-
$b=0^\circ$	$0^\circ 5'$	-
$a=90^\circ$	-	$89^\circ 46'$

That is, *all* the angles are those of the common forms of enargite within the limits of accuracy that the measurement of minute crystals with rather dull c' faces and somewhat striated vertical faces would permit.

Crystals No. 3 and No. 4.—The relatively simple crystals from the cavity walls connect directly with the two other more highly modified crystals here described.

Upon another specimen and so in contact with the massive luzonite as to be, in my opinion, developed from it, were a number of little, bright, highly modified crystals which like Nos. 1 and 2 are much lighter colored on the terminal faces than on the side or prism faces. Crystal No. 3 was the best of these found, and as shown in fig. 3 it proved to include all the forms of Nos. 1 and 2 as well as those of the later described crystal 4. Its size was $\frac{1}{2} \times \frac{7}{8} \times 1^{\text{mm}}$ in the directions \bar{a} , \bar{b} , \bar{c} respectively.

From still another specimen of massive luzonite, but resting upon it rather than growing from it, was a little group of black lustrous crystals, the best of which, crystal No. 4, shown in fig. 4, measured $\frac{3}{8} \times \frac{1}{2} \times \frac{5}{4}$ mm in the directions \tilde{a} , \tilde{b} , \tilde{c} , which,



while differing from all described enargite crystals in the presence of a pyramid, $P=223$, as its most prominent terminal form, connects directly with crystal No. 3 by the fact that this pyramid and all the other forms of the crystal are prominent on crystal 3.

Both crystals were measured in the two-circle goniometer. Crystal No. 3 yielded good to fine signals from twenty-one faces and poorer ones from four others, while crystal No. 4 yielded good signals from twelve faces and poorer from two others. The average results tabulate as follows:

Form.	Crystal.	Number faces.	Measured angles.		Computed enargite angles.	
			ϕ	ρ	ϕ	ρ
c (001)	3	1	----	0°	----	0°
"	4	1	----	0°	----	----
b (010)	3	1*	0°	$89^\circ 49\frac{1}{2}'$	0°	90°
a (100)	3	2	$90^\circ 04\frac{1}{2}'$	90°	90°	90°
"	4	2*	Approx. 90°	90°	----	----
m (110)	3	4	$49^\circ 02'$	90°	$48^\circ 59' 47''$	90°
"	4	4	$48^\circ 57'$	90°	----	----
h (120)	3	4	$29^\circ 56\frac{1}{2}'$	90°	$29^\circ 54' 13''$	90°
"	4	1	$30^\circ 03'$	90°	----	----
l (130)	3	1	$20^\circ 50'$	90°	$20^\circ 58' 38''$	90°
s (011)	3	1*	$0^\circ 1'$	$39^\circ 40'$	0°	$39^\circ 36' 16''$
S (051)	3	2*	0°	$76^\circ 18'$	0°	$76^\circ 24' 40''$
k (101)	3	2	$90^\circ 5'$	$43^\circ 39'$	90°	$43^\circ 34' 56''$
"	4	2	90°	$43^\circ 40\frac{1}{2}'$	----	----
P (223)	3	4	$49^\circ 1\frac{1}{2}'$	$39^\circ 54'$	$48^\circ 59' 47''$	$40^\circ 3' 16''$
	4	4	$48^\circ 59'$	$39^\circ 56'$	----	----

* Poor signals.

The Calculated Angles of Enargite.—The axial elements calculated by Dauber* in 1854 are

$$\tilde{a} : \tilde{b} : \tilde{c} = 0.8711 : 1 : 0.8248$$

based upon angles of $mm = 82^\circ 7'$ and $cs = 39^\circ 31'$.

In 1895 Fletcher† calculated new elements

$$\tilde{a} : \tilde{b} : \tilde{c} = 0.8694 : 1 : 0.8308$$

based upon angles $mm = 82^\circ 0\frac{1}{2}'$ and $ck = 43^\circ 42'$

This value of mm is the average of so many measurements that it cannot well be questioned and it is not far from the angles here obtained since the mean of twenty ϕ angles of 110 and 223 is $48^\circ 57\frac{1}{2}'$ and Fletcher's $mm = 82^\circ 0\frac{1}{2}'$ yields ϕ of $110 = 48^\circ 59\frac{1}{2}'$.

Fletcher's value for \tilde{c} , however, considers only the faces $k = 101$ and is the mean of some fourteen values of ck . The new pyramid, $P = 223$, is represented on crystals Nos. 3 and 4 by eight good faces and the readings especially in crystal 4 are close. The angles ϕ and ρ of 223 in crystal 4 yield $\tilde{a} : \tilde{b} : \tilde{c} = .8698 : 1 : .8241$, essentially those of Fletcher in the case of \tilde{a} but not so near in the case of \tilde{c} .

I have therefore used in my calculation an intermediate value for \tilde{c} of .8274, which is also an approximate mean between the \tilde{c} values of Fletcher and Dauber.

In conclusion, these results show that the crystals which form at the solidification of luzonite and those which form possibly later on luzonite have the angles of enargite. In other words, "luzonite" is not an independent species but merely a variety of enargite.

I base this claim principally on the angles here recorded for the small and relatively simple crystals Nos. 1 and 2, which are types of the cavity-wall crystals so connected with the massive material that it is impossible to doubt that they are the results of its solidification.

Crystal No. 3 I believe to have formed in the same manner but under more favorable conditions, while crystal No. 4 is evidently secondary. The new form $P = 223$, prominent in both, connects them however.

The observed color difference on the terminal faces and vertical faces of the cavity-wall crystals, and crystal No. 3, probably has genetic significance. The recorded analysis by Winkler is of practically pure material, which makes inadmissible a theory of crystallographic regularity in elimination of impurities. The comparative dullness of the basal plane in Nos. 1 and 2 might suggest a light effect explaining the color,

* Pogg. Ann., lxxiii, 383, 1854.

† Mineralogical Magazine, xi, 73, 1895.

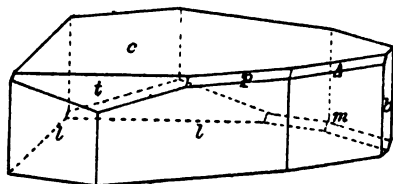
but in crystal No. 3 c is bright and the color is still reddish steel-gray. Tarnish does not seem to explain it, as enargite usually tarnishes a blue-black, and finally the possible deposition of a thin layer of dark-colored enargite observed on pyrite associated with Morococho enargite seems not to explain, since the cleavage on No. 3 is also of the dark gray color.

2. Crystallized Wolframite from Boulder Co., Col.

Mr. Morris K. Jones, of Boulder, Colorado, sent me a sack of tungsten ore from different lodes in the property of the Great Western Exploration and Reduction Co., situated about twelve miles west of the city of Boulder.

The mineral, which varies in the percentage of manganese in the different lodes, occurs in most of the specimens as the cementing material of a brecciated rock composed chiefly of fine-grained quartz and partially decomposed feldspar. The spaces between the angular rock fragments are filled with the

5



crystalline black ore, the crystals often crossing the crevices. Occasionally the ore thickens to a considerable mass.

On breaking the specimens numerous black brilliant little crystals were found, rarely exceeding $1\frac{1}{2}$ to 2^{mm} in their longest dimension. So far as observed none of the crystals is doubly terminated in the direction of the \bar{b} axis, but all have grown out in that direction from the mass. This and the frequent existence at the visible end of a rectangular face or cleavage $b = 010$ suggests at first examination a simple combination of the three pinacoids. The actual form, however, is that shown in figure 5.

Two crystals, each ending in a b cleavage and essentially alike in habit, were measured. Crystal No. 1 was $\frac{3}{8} \times \frac{1}{8} \times \frac{3}{8}^{\text{mm}}$ in the directions a , b , c , and crystal No. 2 a trifle larger.

The forms identified by the measurements were:

Prismatic zone— $l = 210$; $m = 110$; $b = 010$; all yielding good signals from bright decided faces of both crystals.

In addition a signal was obtained from both crystals which closely corresponded to $d = 310$. It was, however, evidently a second element in the striations upon the faces $l = 210$.

The largest face in each crystal was undoubtedly $c = 001$, but these faces were so striated that the series of images gave values for ρ each side of the correct position through four or five degrees, and probably involved various indeterminate domies $h0l$ and $h0\bar{l}$.

The remaining forms determined were $t = 102$ well developed; $\Delta = 112$ minute but bright, and a new form, $p = 214$ occurring as a narrow truncation.

The comparison between the measured and computed coördinate angles for l, m, t, Δ and p is:

Face.	Measured.		Calculated.	
	θ	ρ	θ	ρ
l	$67^\circ 36\frac{1}{2}'$	90°	$67^\circ 34\frac{1}{2}'$	90°
m	$50^\circ 15'$	90°	$50^\circ 27\frac{1}{2}'$	90°
t	$89^\circ 52\frac{1}{2}'$	$28^\circ 10\frac{1}{2}'$	90°	$28^\circ 3'$
Δ	$51^\circ 58'$	$34^\circ 10\frac{1}{2}'$	$50^\circ 53\frac{1}{2}'$	$34^\circ 29'$
p	$68^\circ 45'$	$30^\circ 17'$	$68^\circ 6'$	$30^\circ 8\frac{1}{2}'$

Upon a few of the specimens there were small yellow sphalerite crystals and small crystals of scheelite not suitable for measurement.

3. New Faces on Sylvanite Crystal from Cripple Creek, Col.

Some three or four years ago Mr. F. C. Hamilton purchased some telluride specimens from a dealer at Cripple Creek, Col., and presented them to Columbia University. Among these was a mass of $3\frac{1}{2}$ oz. in weight which consisted almost entirely of large crystals and crystal bunches some of them $20 \times 5^{\text{mm}}$ in length and breadth. Nearly every one of these was partly coated with a thin layer of chalcedony, but many brilliant faces and cleavages were visible.

There were a few smaller crystals upon the mass which were nearly free from chalcedony; one of these was so symmetrical that it was measured under the impression that it was orthorhombic and possibly a highly modified krennerite. The angles, however, quickly proved its identity with sylvanite.

The dimensions of the crystal were approximately $1 \times 1 \times 2^{\text{mm}}$ in the directions a, b, c . For better adjustment the crystal was mounted in the two-circle goniometer with the large $b = (010)$ face parallel to the vertical circle, and centered by this face and the faces of the zone $[100\ 001]$. The results were then transformed.

Twenty-six forms were identified, of which twenty have been previously described by Dr. Chas. Palache* on crystals from Cripple Creek; two others, $M = \bar{1}01$ and $p = 112$, are recorded forms not previously noticed on the crystals from this locality

* This Journal, x, 419, 1900.

and four are new domes $H=102$, $T=103$, $l=203$ and $L=\bar{2}03$. The following angles give the proofs for these previously unrecorded and new forms:

	Measured ρ .	Calculated ρ .
$M=\bar{1}01$	$34^{\circ} 35\frac{1}{2}'$	$34^{\circ} 18'$
$H=102$	$19^{\circ} 19'$	$19^{\circ} 12\frac{1}{2}'$
$l=203$	$24^{\circ} 50\frac{1}{2}'$	$24^{\circ} 55'$
$T=103$	$13^{\circ} 16\frac{1}{2}'$	$13^{\circ} 4\frac{1}{2}'$
$L=\bar{2}03$	$24^{\circ} 13'$	$24^{\circ} 27'$

For the pyramid $p=112$

Measured angles.....	$\phi=31^{\circ} 18'$	$\rho=33^{\circ} 30'$
Calculated angles.....	$\phi=32^{\circ} 0\frac{1}{2}'$	$\rho=33^{\circ} 35\frac{1}{2}'$

The occurring forms and their relative development may be judged by the following tabulation. The forms in the first column are in most cases composed of fine relatively large faces; the largest, however, being the three pinacoids and the three domes 102, $\bar{1}01$, 203. All of these domes are new to the locality.

Type.	Faces yielding fine signals.	Faces yielding good signals.	Faces yielding faint signals.
Pinacoids..	001, 010, 110	----	----
hko	110, 210	310	----
okl	----	011	----
hol	102, 101	203	103
$\bar{h}ol$	$\bar{1}01$, $\bar{2}03$	----	----
hkl	121, 321	111, 112, 123	141, 323, 521
$\bar{h}kl$	$\bar{1}21$, $\bar{3}21$	$\bar{1}11$, $\bar{1}23$	$\bar{5}21$

4. Hematite Parting from Franklin Furnace, N. J.

A mass of ore from Franklin Furnace, N. J., weighing about two pounds, consisted principally of hematite with a very marked rhombohedral parting. With the hematite was calcite also showing a parting (parallel to 0112) and enclosed within the calcite was a broken crystal about one inch in diameter which consisted of a well-defined crust of hematite with the parting, the red streak, the very feeble manganese and very weak magnetism; and a core of franklinite with different luster, no parting, brown streak, decided manganese reaction and decided magnetism.

For record the nearly cubical parting was measured. The signals are not bright and there is a little calcite between the parting surfaces. Two angles of a fragment yielded respectively $94^{\circ} 35'$, $93^{\circ} 52'$ or an average of $94^{\circ} 13'$. The unit rhombohedron angle of hematite is $94^{\circ} 0'$.

Mr. John Crawford, Jr., made triplicate analyses for me of selected material for total iron and for FeO, the result being:

Fe per cent.	FeO per cent.
67.15	1.97
67.07	1.66
67.22	1.54
<hr/>	<hr/>
67.15 average.	1.72 average.

Deducting the 1.34 Fe equivalent to 1.72 FeO leaves 65.81 Fe present as Fe_2O_3 , or 94.00 per cent.

The total analysis becomes:

Insoluble	1.50
CaO calculated to CaCO_3	2.85
Fe_2O_3	94.00
FeO	1.72
	<hr/>
	100.07

Or recalculating the Fe_2O_3 and FeO to 100 per cent.

Fe_2O_3	98.20 per cent.
FeO	1.80 "

Columbia University, June, 1905.

ART. XXXI.—*The Determination of the Optical Character of Birefracting Minerals*; by FRED. EUGENE WRIGHT.

MINERALS are recognized in the thin section chiefly by their crystallographic properties and by the effect they have on transmitted light. The more important optic features used in their microscopic discrimination are color, pleochroism, refractive index, birefringence, optical orientation, angle between the optic axes ($2V$),* and optical character. Of these the latter two are determined in convergent polarized light and are well adapted for general application. They furnish exclusive data as to the nature of a given mineral, and can be accomplished by ordinary petrographic microscopes.

The optical character of a mineral, whether positive or negative, depends by definition solely on the value of the bisector of the acute angle between the optic axes; it is, therefore, independent of the crystal system and pertains to all birefracting minerals. The usual methods available for its determination, however, apply in practice only to uniaxial minerals and to those biaxial minerals for which the angle between the optic axes in air ($2E$) is less than 80° ; if $2E$ exceeds this limit, the traces of the optic axes lie outside of the microscopic field and give rise to uncertainty as to the position of the acute bisectrix, thereby seriously affecting the results. There are several methods, however, which, although not novel in principle, are scarcely recognized in literature, and which practically obviate this difficulty. They are based on phenomena observed in convergent polarized light with nicols crossed and apply equally well to uniaxial and biaxial minerals.

A general consideration of microscopic mineral determination shows conclusively that the optical character of minerals is one of their most useful traits for practical determination since the means employed are simple and of easy application. The following paragraphs aim to present these methods from a working standpoint, the necessary theoretical data appearing in fine print.

The crystal sections of birefracting minerals, from which decisive interference figures can be obtained, are those cut exactly or nearly perpendicular to the bisectrices of the optic axes, to the optic axes, and parallel to the plane of the optic axes. These sections and the methods applicable to them can be discussed for all birefracting substances if uniaxial minerals are treated as a limiting case of biaxial minerals.

* The use of the term optic binormal in place of "optic axes" as proposed by Mr. L. Fletcher in his treatise on The Optical Indicatrix may be an improvement on the original term, but since the distinction implied by the words uniaxial and biaxial is in use in all languages, is convenient and causes no confusion, it is probable that the original designation will remain.

The figures 1-6, used to illustrate the methods, were obtained in part by graphical and in part by mathematical means based on the law of Fresnel, that the planes of polarization for rays traveling in any direction bisect the angles between the planes containing the ray and the two optic axes respectively; in other words, the directions of extinction for any face bisect the angles between the projections of the optic axes on the face.

Plates cut perpendicular to the acute bisectrix.

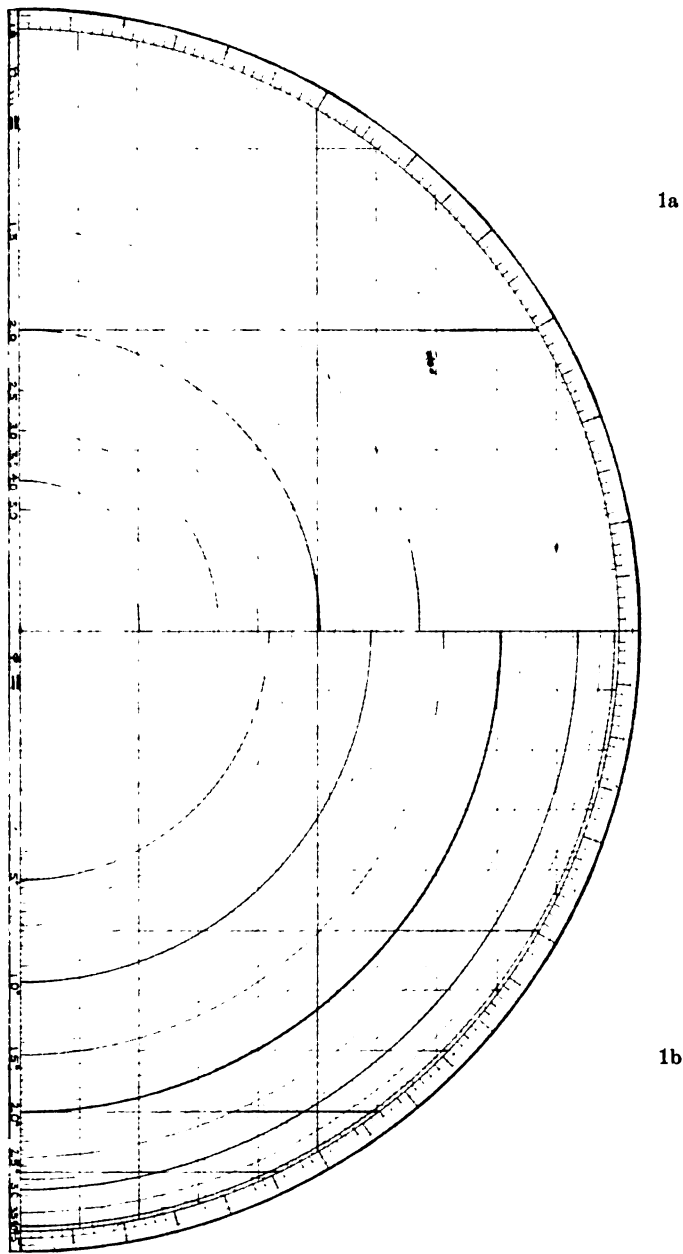
For birefracting minerals in which $2E$ is less than 80° , the methods ordinarily described in text-books are applicable and satisfactory. Both optic axes appear then in the field, and the optical character can be ascertained in convergent polarized light by observing the change in position of the lemniscatic interference curves in alternate quadrants on the insertion of a quartz wedge or a plate showing the interference-color red of the first order, or a quarter-undulation mica plate. The numerical value of $2E$ can also be measured on the same section by the Bertrand-Mallard* method described below. For minerals whose $2E$ is greater than 80° , a method described by Michel Lévy† for determining whether the section is perpendicular to the obtuse or the acute bisectrix can be used to advantage. It consists in observing the angle of revolution of the stage from the position where the black achromatic curves of the interference figure form a cross to that at which they are tangent to a given circle (usually field of the microscope). From this angle $2E$ can be determined, and from it in turn the true optic axial angle ($2V$), if the medium index of refraction of the substance be known.

It can be proved both mathematically and graphically that the dark achromatic hyperbolas, which form during the revolution of the stage, pass through the traces of the optic axes and recede from the field along the diagonals of the principal planes of the nicols. Practically, the course of procedure is to find a plate cut perpendicular to the bisectrix, to record the angle of revolution of the stage from the point where the dark hyperbolas intersect to that at which they are tangent to a given circle within the field of vision. From this angle the corresponding axial angle in air can be obtained by using fig. 1a, provided the Mallard constant of the microscope has been previously determined. If the medium refractive index of the mineral is also given, it is possible to convert $2E$ into $2V$ by means of fig. 1b.

* E. Bertrand in Mallard, *Miner. physique*, 11, 418. E. Mallard, *Sur la mesure de l'angle des axes optiques*. *Bull. Soc. miner.*, 1882, page 77 et seq.

† Michel Lévy, *Minéraux des Roches*, 94-95.

FIG. 1.



Bertrand-Mallard method for measuring the optic axial angle ($2E$) under the microscope. Mallard has shown that the distance of the trace of an optic axis from the center of the interference figure is proportional to the sine of the angle which the optic axis makes with the axis of the microscope; that, if the distance D be measured by means of a micrometer ocular, the angle E can be figured from the formula

$$\sin E = \frac{D}{K}$$

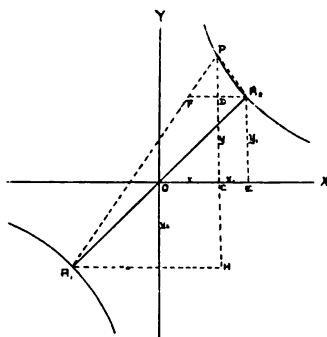
in which K is the constant of the microscope to be determined once for all on a substance whose $2E$ is known. By drawing a circle of radius K in fig. 1a (once for all), the angle E corresponding to any number of divisions of the micrometer ocular is then the angle in the figure included between its base and the radius passing through the intersection of the arc K with the horizontal line at the distance D from the base line. To convert $2E$ into $2V$ use fig. 1a, which was derived from the formula

$$\sin V = \frac{\sin E}{n_m}$$

n_m being the medium refractive index of the substance. The angle $2V$ is then the angle on the degree circle included between the base line and the horizontal line which passes through the intersection of the radius E and the given refractive index arc.

Michel Lévy method. Michel Lévy has developed a formula from which approximate values of the axial angle $2E$ can be calculated, provided the index of refraction of the objective lens in which the interference figure is observed be known. As this, however, is not generally the case, a modification of the formula by introducing Mallard's constant in place of the refractive index is better suited to actual practice.

FIG. 2.



In fig. 2* let the plane of the paper represent the section perpendicular to the bisector of the acute optic axial angle and the figure itself the achromatic lines observed in convergent polar-

* Compare Preston, *Theory of Light*, 3d ed., pp. 400-401.

ized light; A_1A_2 , the projection of the optic axes, and P that of any ray in the achromatic hyperbola. Fresnel's law states that the planes of polarization of rays traveling in any direction P are the bisectors of the angles between the planes A_1P and A_2P . For small angles of incidence, the traces of the planes of polarization of the rays will approximately coincide with the bisectors of the angle A_1PA_2 . Since P is a point of the achromatic curve, the bisector of the angle A_1PA_2 must be parallel to one of the principal planes of the nicols. The triangle FPA_2 is then isosceles, and the triangles PFD and PDA_2 are similar. Therefore

$$\frac{x_1 - x}{y - y_1} = \frac{x + x_1}{y + y_1}, \text{ or} \quad (1)$$

$$xy = x_1y_1 \quad (2)$$

the equation of an equilateral hyperbola. In order that this curve be tangent to a circle, its tangent must be perpendicular to the radius the equation for which is

$$y = -\frac{1}{\frac{dy}{dx}} x \quad (3)$$

By substituting the value of $\frac{dy}{dx}$ from (2), (3) becomes

$$x = y \quad (4)$$

which shows that the hyperbolic curves are tangent to the circles along the diagonals of the nicols. For these points (2) reads

$$x^2 = x_1y_1 \quad (5)$$

Transforming (5) to polar coördinates, we find

$$\rho^2 = r^2 \sin 2\phi \quad (6)$$

From Mallard's method above, it is evident that

$$r = K \sin E$$

$$\text{and } \rho = K \sin O$$

$$\text{Therefore, } \sin E = \frac{\sin O}{\sqrt{\sin 2\phi}} \quad (7)$$

where sine O is the constant of the circle used and to be determined once for all by the Mallard method. For any given angle of revolution (ϕ) the corresponding E can be found by finding in fig. 1b the intersection of the horizontal line at the distance sine O from the base line with that arc which corresponds to the angle ϕ . $2E$ can then be reduced to $2V$ by fig. 1a, if the medium index of refraction be known.

Owing to the width of the achromatic curves, the results attained by this method are only approximate but of sufficient accuracy to be useful in many instances. The angles ϕ can also be figured for sections not exactly perpendicular to the bisectrix; they possess, however, only slight practical value.

The mathematical formula above is only an approximate one, while a graphic method can be applied which is theoretically correct and by which more accurate results can be obtained. The method has been used by Michel Lévy, Viola,* von Fedorow and others in their feldspar studies and is well adapted for general use in the study of optical phenomena.

The lines along which any face will extinguish can be found by passing planes through the normal to the face and the optic axes respectively, and bisecting the traces of these planes on the face. In order to do this readily, a stereographic projection of the optic axes in any desired position should first be made. By a revolution about each of two horizontal axes in the principal planes in the nicols, any face normal can be brought to coincide with the pole of the projection and the face with that of the paper. The bisectors of the angles between the straight lines drawn through the pole of the projection and the optic axes in their new positions are then the desired directions. The achromatic black hyperbolas of the interference figure correspond to those face-normals whose extinction lines are parallel to the axes of revolution of the projection. In the projection the achromatic lines, however, do not appear as they do when observed under the microscope, for its interference figure can be considered with slight error as an orthographic projection of the rays on a sphere, as shown by Mallard's formula above. The curves of the stereographic projection must therefore be replotted by making the polar distance $\sin E$ instead of $\tan \frac{E}{2}$ as it is in the stereographic projection. The general aspect of the curves is not changed by this transformation. The graphic method has been applied to the methods below with satisfactory results. (Figs. 4 and 6.)

The interference figure from the section perpendicular to the obtuse bisectrix differs from the above only in the wider optic axial angle, which can be measured by the same methods.

Plate perpendicular to an optic axis.

The interference figure obtained from this plate consists ordinarily of a black achromatic bar which revolves in a direction opposite to that of the stage. In general the bar is a straight line only when it is parallel to the planes of polarization of the nicols; in the intermediate positions it is more or less convex, depending on the angle between the optic axes. If $2E$, however is equal to 90° , the curve is a straight line in all positions for the usual microscopic field of vision.

* Michel Lévy, *Sur la détermination des feldspaths*, 1894, pp. 15-20. C. Viola, *Zeitschr. für Kryst.*, xxx, 232, xxxi, 484, xxxii, 305. E. von Fedorow, *Zeitschr. für Kryst.*, xxxi, 579, xxxii, 246.

FIG. 3.

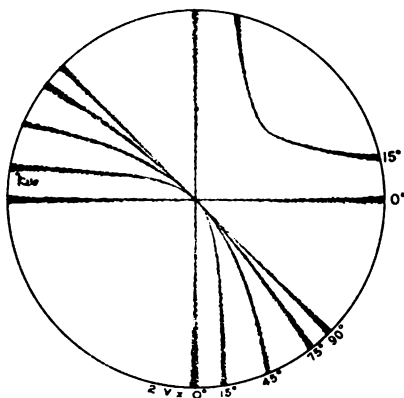
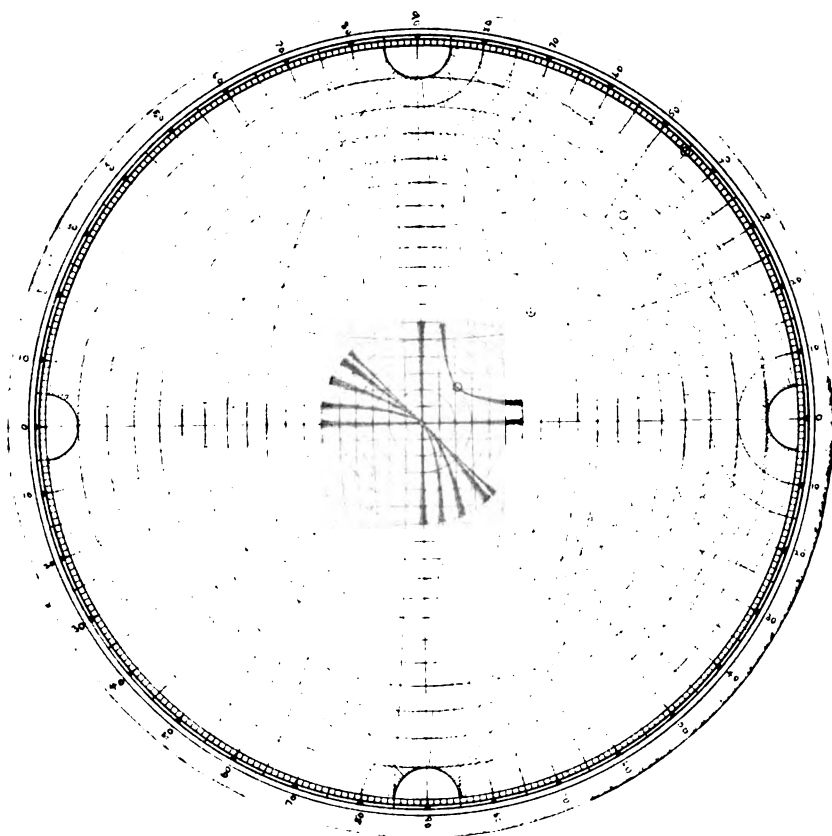


FIG. 4.



the equation of an equilateral hyperbola passing through the zero coördinate point with asymptotes parallel to the X and Y axes. For the special case under consideration where $x_1 = y_1$, the formula becomes

$$y = 1 - \frac{1}{x - x_1} \quad (3)$$

From (3) the curves of fig. 3 were plotted in gnomonic projection.

For $x_1 = \infty$, equation 3 becomes

$$x = y$$

the equation of a straight line passing through the zero point at an angle of 45° with the coördinate axes. If the formula of Mallard were exact, x_1 could not assume a value greater than 1 (sine 90°); since it is approximately correct only for small angles, the above remark does not obtain. The gnomonic projection was, therefore used in fig. 3 instead of the orthographic.

In such limiting cases the graphic method gives more satisfactory results and is in general better suited to the study of optical phenomena. In fig. 4, the stereographic plat with curves for optic axial angles 0° , 15° , 45° , 75° , and 90° is given. Their course in the vicinity of the pole of the projection only is represented since it corresponds to that portion which is seen under the microscope.

*Plate parallel to the plane of the optic axes.**

In the uniaxial minerals this plate corresponds to any section in the prism zone.

The interference figure from the section can be recognized by the fact that in the position of darkness the entire field is practically dark and that a small revolution of the stage (5°) will cause the faint hyperbola to recede entirely from the field of vision. In the diagonal position the colored interference curves have the form of hyperbolas.

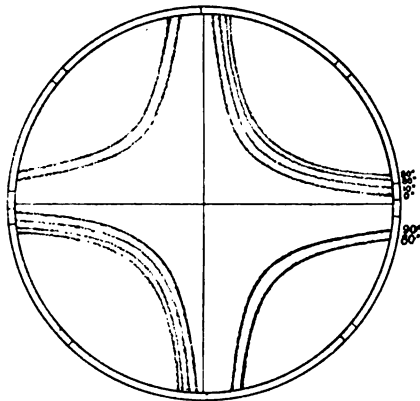
Since ordinary approximate methods of calculation do not apply to this section, the graphic method with the stereographic projection plat as base was adopted. The result, as depicted by the curves of fig. 6, shows that the recession of the dark achromatic lines for the optic axial angles $2V = 0^\circ$, 10° , 80° , and 90° after a revolution of 1° of the stage is very marked, and that, except in the limiting case of $2V = 90^\circ$, the dark hyperbolas pass out of the field most slowly in the direction of the acute bisectrix. For $2V = 90^\circ$ the hyperbolas in all quadrants recede from the center with equal rapidity. In fig. 6

* Compare F. E. Wright, this Journal, xvii, 387-391.

the lines between the outer and inner circles represent the actual position of the bisectrices and optic axes under the conditions stated.

Owing to the fact that for this section the angles of extinction are very low for all rays whose angle of incidence is small, the intensity of the rays adjacent to those of the achromatic curve is also low, since it varies with the square of the sine of

FIG. 6.



the angle ρ between the planes of polarization of the nicols and that of the section according to the formula

$$I = \sin^2 2\rho \sin^2 \frac{\pi}{\lambda} (o-e)$$

The black curves are therefore indistinct and require careful scrutiny to be observed at all.

The colored hyperbolic interference curves which appear in the interference figure most sharply in the diagonal position of the section can also be used to locate the direction of the acute bisectrix. It can be proved in several different ways that the acute bisectrix is generally direction of less birefringence than the obtuse bisectrix. The birefringence of any section can be figured approximately by the formula

$$\gamma' - \alpha' = (\gamma - \alpha) \sin \theta_1 \sin \theta_2,$$

where γ' and α' denote the maximum and minimum refractive indices of the given section, γ and α those of the mineral, θ_1 and θ_2 , the angles between the normal to the section and the

optic axes respectively. The formula indicates clearly that, except in the limiting case of $2V=90^\circ$, the birefringence for sections in the alternate quadrants containing the acute bisectrix is less than that for corresponding sections in the two remaining quadrants. The rule resulting from this fact is that the interference colors for points in the quadrants containing the acute bisectrix are lower than those for corresponding points in the direction of the obtuse bisectrix.

After the direction of the acute bisectrix has been found by one of the above methods, its value (c or a) can be readily ascertained by ordinary methods either in parallel or convergent polarized light.

Summary.

In the practical determination of minerals under the microscope advantage is taken chiefly of those properties which are definite in character and which can be readily ascertained. Of these the optical character is one of the most useful since it applies to all birefracting minerals and can be determined in convergent polarized light on plates cut along one of several different directions :

1. On plates perpendicular to the acute bisectrix, by observing the direction of movement of the curves of the interference figure on the insertion of a quartz wedge, mica plate, or plate showing the interference color red of the first order. If the loci of the optic axes lie outside of the field, determine whether the plate is perpendicular to the obtuse or acute bisectrix by measuring the optic axial angle in air by the modification of the Michel Lévy method described on page 288. The reduction of the observed optic axial angle to that in the crystal can be accomplished only when the medium refractive index of the substance is known and then easily by fig. 1.

2. On a plate perpendicular to an optic axis by noting that, when the black achromatic bar lies in a position diagonal to that of the principal planes of the nicols, its convex side points toward the acute bisectrix and that on the insertion of a plate showing the interference color red of the first order, the convex side will be colored blue if the arrow (n) of the inserted plate lies in the plane of the optic axes and the mineral is optically negative ; if the blue spot lies on the concave side of the bar and the arrow of the plate still lies in the plane of the optic axes, the mineral is optically positive. This method is applicable whenever the curvature of the achromatic bar can be observed. The section is moreover easy to find because in parallel polarized light with nicols crossed it remains nearly dark for all positions of the stage.

3. On a plate parallel to the plane of the optic axes the direction of the acute bisectrix can be located by two different methods:

a. Revolve mineral from the position of darkness through a small angle and note that the direction in which the faint dark hyperbolas recede from the field is that of the acute bisectrix.
b. In the diagonal position of the interference figure observe the interference colors of corresponding points in adjacent quadrants and note that the points in the direction of the acute bisectrix show the lower interference colors. In both cases the value of the acute bisectrix (c or a) can be determined either in convergent or parallel polarized light by the usual methods and thus the optical character of the mineral be ascertained.

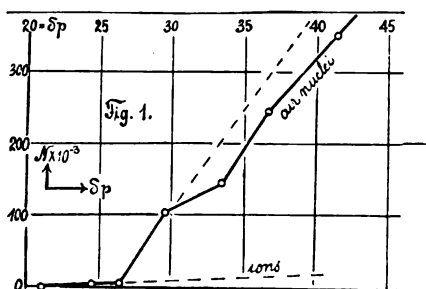
U. S. Geological Survey, Washington.

ART. XXXII.—On Groups of Efficient Nuclei in Dust-Free Air; by C. BARUS.

1. *Dust-free Air*.—By this term I refer to atmospheric air filtered with extreme slowness (through large wide filter of packed cotton) and thereafter left without interference for two or more hours. Such air shows a high fog limit. In the fog chamber used the coronal condensation begins at a pressure difference of about $\delta p = 26$ cm., rain-like condensation at $\delta p = 21$ cm.

In the present experiments all tests are made at $\delta p = 41.5$ cm., at a pressure difference therefore much above the fog limit, and probably approaching the condensing power of the apparatus. The number of nuclei computed from the coronas observed is an approximation merely, as the constants needed for the very large range of variation in question are not available. Nevertheless, if the same δp is used throughout, the nucleations obtained are immediately comparable. With these reservations* the number of nuclei found in the dust-free air and at the δp in question is about 380×10^3 to 400×10^3 per cm^3 . It is obvious, moreover, that these nuclei are excessively small, much smaller than ions, smaller even than those which would respond to smaller exhaustions, exceeding $\delta p = 26$ cm.

In figure 1 I have given an example of these relations. Between $\delta p = 21$ and 26 (for this



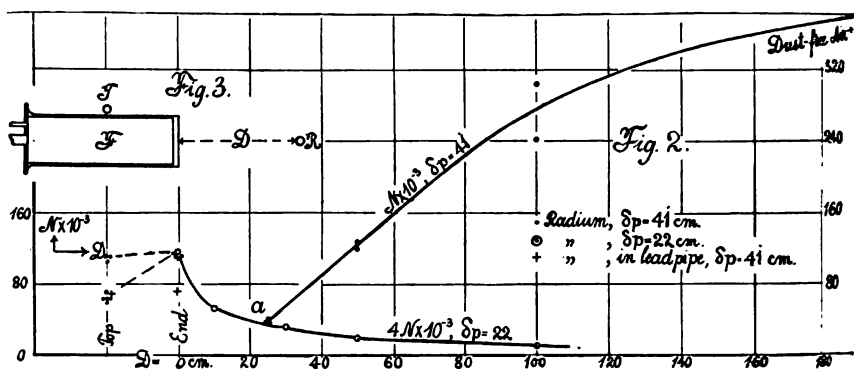
apparatus) condensation probably takes place largely on ions, above that on the nuclei of dust-free air. The upper dotted line shows the limit of value found, the latter being variable because (as will appear more clearly below) the ionization of atmospheric air is essentially variable. Though relatively small in number, the ions from their larger size probably capture much of the moisture.

2. *Effect of Radium*.—Now let the fog-chamber (fig. 3) be subjected to the radiations from weak radium (10,000 \times , 10 mg.) contained in a thin hermetically sealed aluminum tube. As the walls of the fog-chamber are .3 cm. thick and

* The nuclei are supposed to be removed by exhaustion, faster than they can be restored, either by radiation or by the molecular mechanism.

the end (bottom) toward the tube nearly 1 cm. thick, γ -rays only will penetrate into the inside apart from the secondary radiation there produced. In figure 3 F is the cylindrical fog-chamber, R the radium tube at an axial distance D from the nearer end. In addition to this the radium was also tested at T (top) in the figure, where it is nearest the body of dust-free air under experiment.

Within the fog-chamber the coronas are everywhere normal and of the same size, in spite of the axial length of 45 cm. available. This is a singular result when contrasted with the marked positional effect observed for the case of radium placed at the different distances D outside of the chamber. The data investigated are shown in the curve (fig. 2), where the abscissas are the distances D and the ordinates the number of efficient nuclei per cm^3 .



It follows from the graph that as the radium is brought in an axial direction from ∞ to the end of the fog-chamber, the number of efficient nuclei in the dust-free air contained is gradually but enormously reduced to a minimum for $D = 25$ cm. (about), after which the number again increases to the maximum at $D = 0$. Curiously enough, if the radium is further approached to the body of the air by being placed at T , the number of nuclei does not increase; in some observations it even diminishes.

If the radium is enclosed in a long thick lead tube (60 cm. long, walls .5 cm. thick), the nucleation is but moderately reduced (see fig. 2, crosses), showing that γ -rays are in question.

4. *Cause of the minimum.*—This is easily explained since the ions are relatively large bodies and relatively few in number as compared with the nuclei of dust-free air for the same δp . Hence the ions virtually capture the moisture more and more fully as their number, with diminishing distance D , becomes greater. At $D = 25$ cm. probably the whole of the

moisture is condensed on ions, and as their number increases as D vanishes, the minimum in question results.

In fact it was shown elsewhere, that below the fog-limit of air, the nucleation observed and due purely to radium at different distances D , is for example ($\delta p = 22$)

$D =$	0	10	30	50	100	
$N \times 10^{-3}$	120	50	32	20	12	etc.

agreeing in character as far as may be expected with the data here in question. These data multiplied by 4, i. e., $4n \times 10^{-3}$, are also given in figure 2 for comparison. Hence the ions caught at $\delta p = 41.5$ are about four times more numerous than at $\delta p = 22$, and correspondingly smaller. They are, therefore, markedly graded, but nevertheless, as a group, throughout much smaller than the nuclei of dust-free air so long as the radiant field is appreciable. Whether the latter are agglomerated under the influence of radiation to make the ions (as would seem more probable), or whether the ions are made from the molecules themselves so that the ions and the nuclei of dust-free air are present together, is a question beyond the scope of the method. While the number of nuclei continually grows smaller, with diminishing D , the efficient or capturing nuclei may nevertheless increase again below a certain D , seeing that the nuclei in dust-free air are enormously in excess, only a few of which are caught even in the absence of radium.

4. *Cause of the maximum.*—It is more difficult to account for the result that the same nucleation is observed wherever the radium touches the elongated fog-chamber. In other words, radium at the end of the chamber produces at least the same nucleation as when at the top, although the distances from the center of mass of the glass are as 3 to 1. The same kind of explanation already given in § 3 may possibly hold. The radium tube when placed on the top (T in figure 3) and in contact with thinner glass, may act with sufficient intensity to admit of the formation in turn of a group of nuclei larger than ions. This is what actually occurs in the case of X-rays. But it is more probably connected with the uniform distribution of nuclei within the chamber (§ 1) and in some way referable to secondary radiation evoked within the chamber. Secondary radiators added on the outside are quite without effect.

5. *General Conclusion.*—The occurrence of a continuous succession of groups or gradations of nuclei in the curve of figure 2, each of which groups constitutes a condition of chemical equilibrium for the given radiating environment, is suggestive. In the first place, it may be recalled that the nuclei of dust-free air are an essential part of this body as much as the molecules themselves. Such nuclei if withdrawn by precipi-

tation are at once restored. Again air left without interference for days shows a maximum of this nucleation for the given conditions of exhaustion when all foreign nucleation must have vanished. Indeed the molecules themselves may be treated as a continuous part of the nucleation in question, the frequency of occurrence being a maximum for the molecular dimensions.

Furthermore in the presence of radium the character of the phenomenon is the same, only the nuclei are larger. If withdrawn by precipitation, they are at once restored. They are an essential part of the air in the new environment.

It is natural to compare the particular nuclear status introduced in the latter case by a particular kind of radiation (γ rays), with the former case of dust-free air in the absence of recognized radiation. In other words, quite apart from the details of the mechanism, chemical agglomeration might be considered referable to an unknown radiant field, but be otherwise essentially alike in kind to the much coarser nucleations observed in the known radiant fields of the above experiments. But the effect of radium, however distant, is always virtually an increase of the size of the air nuclei and a decrease of their number. Hence if we were to fancy that the nucleation (not the ions, of course) of non-energized dust-free air responds to its own radiant environment, this radiation would have to be special in kind.

Returning to the case of the gamma rays, fig. 2, (or of the X-rays coming from a distance,) let me recall that the effective radiation within the fog chamber is everywhere the same and the same in all directions. Hence whether the radiation be corpuscular or (in other cases) undulatory, the interior is nothing less than an ideal Lesage medium; and there must therefore be a tendency at least to agglomerate the colloidal nuclei of dust-free air into fleeting nuclei or ions, so long as the radiation lasts. When it ceases the ions are free to fall apart, so far as external influence goes, as they actually do. Furthermore since the pressure so obtained would increase with the number of corpuscles per cubic cm. and with the square of their velocity, it is conceivable that with increasing electrification this pressure would become strong enough to bring about permanent union of the aggregates, corresponding to the observed continuous transition of the ions into persistent nuclei, produced by the X-rays. Again a different nucleus would presumably correspond to the bombardment of the negative corpuscles as compared with the residual positive quantities. Finally, if any physical or chemical process like combustion or ignition or electric charge, or the case of phosphorus, etc. is accompanied by intense ionization, one would for the same reason anticipate the presence of nuclei in such a field.

Brown University, Providence.

ART. XXXIII.—*Studies in the Cyperaceæ*; by THEO. HOLM.
XXIV. New or little known *Carices* from Northwest America. (With 18 figures, drawn from nature by the author.)

WITH the object of preparing a treatise of the genus *Carex* as represented in the northwestern part of this continent the writer has examined several very extensive collections, containing a vast number of specimens, among which some few have been observed as imperfectly understood or as hitherto undescribed. Inasmuch as the treatment of the genus in a subsequent paper will be from a geographical point of view, we prefer to publish the diagnoses of the new species separately with some remarks upon their affinities.

These species are :

Carex limnæa sp. n. (figs. 1–3).

Rhizome vertical with ascending shoots and light brown, fibrillose leaf-sheaths; leaves a little shorter than the culm, narrow, but flat, glaucous, scabrous along the margins; culm about 60^{cm} in height, erect or slightly curved above, very slender, triangular, scabrous, phyllopodic; spikes 3 to 5, but mostly 4, the terminal staminate or, sometimes, androgynous, the lateral pistillate, the uppermost contiguous, the lowest remote, sessile to shortly peduncled, erect, not very dense-flowered, cylindric, about 2^{cm} in length, subtended by sheathless, foliaceous bracts, the lowest one often exceeding the inflorescence; scale of staminate spike lanceolate, light purplish-brown with green midvein; scale of pistillate spike oblong, obtuse, black with hyaline apex and greenish midvein, shorter than the perigynium; perigynium stipitate, slightly spreading, narrowly elliptical, granular, plano-convex, prominently many-nerved on the outer (convex) face, three-nerved on the inner, pale green with a black, entire and very distinct beak; stigmata 2, style long and exserted.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1456); Four-mile Lake, Klamath County, in meadows, and between Diamond and Crescent Lakes, Cascade Mountains.

The graceful habit of this species reminds us more of *C. rhomboidea* than of *C. vulgaris*, but when we, nevertheless, prefer to place it nearer *C. vulgaris* it is on account of the structure of the perigynium, narrowly elliptical and prominently many-nerved.

Carex brachypoda sp. n. (figs. 4–6).

Rhizome short with ascending shoots and persisting, dark brown leaf-sheaths; leaves shorter than the culm, relatively broad (about 5^{mm}) and flat, deep green, scabrous along the margins and lower face, glabrous above; culm about 35^{cm} in height, erect, stiff, triangular, scabrous, phyllopodic; spikes 3 to 4, mostly 4, the terminal staminate, the lateral pistillate, somewhat remote, sessile or the lowest one short-peduncled, erect, dense-flowered, cylindrical, from 1 to 2^{cm} in length, subtended by sheathless bracts with narrow blades much shorter than the inflorescence; scale of staminate spike lanceolate, reddish brown with pale midvein; scale of pistillate spike ovate, obtuse, black with green, not excurrent midvein, a little shorter than the perigynium; perigynium minutely stipitate, erect, almost orbicular, granular and denticulate along the margins above, compressed, nerveless, pale green, the minute beak dark purple with the orifice entire, papillose; stigmata 2.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1455).

The affinity of this species is with *C. gymnoclada*, but it differs from this by the perigynium for instance, which is more roundish, denticulate and very shortly beaked.

Carex pachystoma sp. n. (figs. 7–8).

Rhizome caespitose with strong roots and persisting, reddish leaf-sheaths; leaves almost as long as the culm, quite broad and flat (0.5^{cm}), glabrous, light green; culm from 30 to 56^{cm} in height, erect, somewhat slender, triangular, scabrous, phyllopodic; spikes 4 to 6, the terminal and uppermost lateral staminate, the others pistillate, remote or the uppermost contiguous, all, especially the lower ones, slenderly peduncled, erect or spreading, dense-flowered except at the base, from 3 to 5^{cm} in length, subtended by sheathless, leafy bracts about as long as the inflorescence or a little longer; scale of staminate spike lanceolate, obtuse, purplish brown with green midvein; scale of pistillate spike lanceolate, mucronate, deep purple with broad, green midvein, narrower, but longer than the perigynium; perigynium sessile, slightly spreading, elliptical, granular, compressed, nerveless, green or purplish-spotted above, the beak short and thick, sparingly denticulate, the orifice very narrow, slightly emarginate on outer face; stigmata 2.

Oregon: Crater Lake National Park, Anna Creek Canyon, near the falls (No. 1362) and near Odell Lake, Klamath County (No. 520), collected by Messrs. Applegate and Coville.

Washington: Springy places, northern slope of Mt. Adams, and Falcon Valley, W. Klickitat County (No. 2959), by Mr. W. Suksdorf.

The species may be placed between *C. variabilis* and *C. lenticularis*, although it shows some approach to *C. acutina*, though merely in respect to its habit. We have examined a number of specimens and are unable to refer the plant to either of those mentioned above.

Carex Nebraskensis Dew.

Habitually and in several other respects this species seems inseparable from the *Microrhyncha*, but we have placed it* as one of the most evolute types of these on account of the bidentate beak of the perigynium. It is excellently described by Boott,† and well marked by the strong stolons covered by brown scale-like leaves, which are never shining, by the pale, glaucous leaves and especially by the perigynium with its prominent ribs and bidentate beak. In the extensive collection of Mr. Suksdorf we found several specimens, which were somewhat like this species, but a careful examination of the spikes convinced us that these could not safely be referred to the species, nor ought they to be considered as simply varieties, hence we prefer to describe them as two distinct species: *C. eurycarpa* and *C. oxycarpa*.

Carex eurycarpa sp. n. (figs. 9–10).

Rhizome stoloniferous with persisting, brown leaf-sheaths and strong roots; leaves half as long as the culm, narrow (3^{mm}), carinate, light green, scabrous along the keel and margins; culm 60^{cm} in height, erect, slender but somewhat stiff, scabrous, triangular, phyllopodic; spikes 3 to 5, mostly 5, the terminal and, sometimes, the uppermost lateral staminate, the others purely pistillate, all remote; the pistillate short-peduncled, erect, dense-flowered except towards the base, until 5^{cm} in length, cylindric, but relatively thin, subtended by narrow, sheathless bracts, about as long as the inflorescence; scale of staminate spike oblong, obtuse, light brown with pale midvein and narrow, hyaline margins; scale of pistillate spike lanceolate, acute, blackish with pale, not excurrent, midvein, narrower, but about as long as the perigynium; perigynium sessile or nearly so, erect, roundish, granular, slightly plano-convex, prominently many-nerved on both faces, brownish, the beak short, emarginate; stigmata 2.

Washington: W. Klickitat County, Falcon Valley, collected by Mr. W. Suksdorf, June, 1886 (Nos. 1284 and 2962).

Carex oxycarpa sp. n. (figs. 11–12).

Rhizome stoloniferous with strong roots and persisting, brown leaf-sheaths; leaves a little shorter than the culm, nar-

* The author: Gregea Caricum. (This Journal, vol. xvi, p. 457, 1903.)

† Ill. gen. Carex, vol. iv, p. 175 and plate 592.

row (4^{mm}), carinate, light green, scabrous; culm about 75^{cm} in height, erect, slender, but somewhat stiff, triangular, scabrous, phyllopodic; spikes 4 to 5, the terminal staminate, long-peduncled, the lateral pistillate, contiguous, seldom remote, short-peduncled, erect, dense-flowered, cylindric, from 2 to 4^{cm} in length, subtended by sheathless, narrow, foliaceous bracts, the lowest one exceeding the inflorescence; scale of staminate spike oblong, obtuse, light reddish-brown with pale midvein; scale of pistillate spike lanceolate, acute, blackish with pale, not excurrent midvein, narrower, but about as long as the perigynium; perigynium sessile, broadly elliptical, granular, compressed, prominently 3-nerved, brownish, prominently denticulate along the margins from near the base to the short, emarginate beak; stigmata 2.

Washington: W. Klickitat County, meadows near the Columbia, collected by Mr. W. Suksdorf, June, 1885 (No. 816).

Of these *C. eurycarpa* is a very slender plant and much more so than any of the numerous specimens of *C. Nebraskaensis*, which we have studied. The broad perigynium with the beak merely emarginate constitutes, also, a good distinction. In the other, *C. oxycarpa*, we have, also, a plant of slender habit, but the spikes are relatively heavy, and the perigynium is here merely 3-nerved and with the margins quite prominently denticulate from the base to the emarginate beak.

The affinity of these two species is unquestionably with *C. Nebraskaensis* Dew., next to which they should be placed in the system.

Carex campylocarpa sp. n. (figs. 13-15).

Rhizome with short stolons and purplish, persisting leaf-sheaths; leaves shorter than the culm, narrow, but flat, scabrous along the margins and on the lower face; culm about 40^{cm} in height, erect, stiff, triangular, scabrous, phyllopodic; spikes 3 to 4, mostly 3, the terminal staminate, the lateral pistillate; remote, sessile or nearly so, erect, dense-flowered, short cylindric to ovoid, from $\frac{1}{2}$ to 1^{cm} in length, subtended by sheathless, foliaceous bracts, shorter than the inflorescence; scale of staminate spike lanceolate, obtuse, purplish brown with pale midvein; scale of pistillate spike ovate, obtuse, blackish with the midvein faintly visible and the margins narrow, hyaline, much shorter than the perigynium; perigynium shortly stipitate, spreading, elliptical-oblong, granular and prominently denticulate along the upper margins, turgid, nerveless, pale green with purplish spots and streaks, the beak quite prominent, excurved, the orifice entire; stigmata 2, style not exerted.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1457).

The systematic position of this species seems naturally to be among the *Microrhyncha*, but as a deviating type on account of the excurved beak of the perigynium, and if it were not for the distinct marginal denticulation of the perigynium and its slender shape the species would resemble *C. scopulorum* to some extent. A perigynium of this kind is somewhat unusual within the representatives of the grex, but is, as we remember, very characteristic of the *Spirostachya*; in these, however, the beak is generally bifid and more distinctly differentiated from the body. The species may be placed next to *C. scopulorum*.

Carex cryptochlæna sp. n. (fig. 16).

Rhizome caespitose with purplish, persisting leaf-sheaths; leaves about half as long as the culm, broad (about 1^{cm}) and flat, glabrous except along the margins; culm from 70 to 90^{cm} in height, erect and stiff, triangular, scabrous along the edges, phyllopodic; spikes from 4 to 7, the terminal and frequently the uppermost lateral staminate, the others pistillate or androgynous, contiguous or the lower ones remote, sessile or short-peduncled, erect or spreading, seldom nodding, dense-flowered, subtended by sheathless, foliaceous, broad bracts of which the lower ones exceed the inflorescence; scale of staminate spike elliptical-oblong, acute, light reddish-brown with pale midvein; scale of pistillate spike lanceolate, sharply pointed, deep purplish with broad, greenish midvein, exceeding the perigynium; perigynium almost sessile, erect, broadly elliptic to roundish, nerveless, pale green, granular, sparingly denticulate near the minute, entire beak; stigmata 2.

Alaska: Kussloff, on sands with Elymus, collected by Dr. Walter H. Evans, July, 1898 (No. 618), and Seldovia near mouth of Cook inlet by Prof. C. V. Piper, August, 1904 (Nos. 4818 and 4819).

This species is somewhat remarkable on account of its resemblance to *Carex cryptocarpa*, so far as concerns the structure of the spikes, the deep-purplish, lanceolate scales and the broad pale-green perigynia. But it shows, on the other hand, a striking contrast to this species, *C. cryptocarpa*, not only by the almost sessile and mostly erect pistillate spikes, but also by its very broad leaves, the basal and the bracts. Habitually the species does not resemble *C. cryptocarpa*, but, to some extent, Drejer's *C. hæmatolepis* or certain very robust forms of *C. salina*; it appears, however, to be distinct from these, and as a type intermediate between the true *Salina* and *C. cryptocarpa* Mey.

Carex luzulaefolia W. Boott var. *strobilantha* nob. (fig. 18).

Taller and more robust than the typical plant; the spikes thick and very compact-flowered; scales of staminate and pistil-

late spikes mostly mucronate; perigynium glabrous throughout, faintly nerved on the inner face, nearly sessile, roundish in outline and terminated by a very distinct, bidentate beak.

California: Above Donner Pass in Placer County, in a subalpine meadow, where snow-drifts lie late, and usually near granite rocks, collected by Mr. A. A. Heller, August, 1903 (No. 7187).

In the specimens of this new variety the rhizome is densely matted with ascending shoots and covered by dark, brownish fibers from the old leaf-sheaths. The leaves are very broad, but much shorter than the culms. The heavy, deep-brown spikes remind of small cones, hence the name "*strobilantha*," and there is quite a variation in respect to their number, position and the distribution of the sexes. We noticed the following instances in 26 specimens:

2 staminate and 3 pistillate spikes in 14 specimens.							
1	"	"	3	"	"	5	"
2	"	"	4	"	"	2	"
1	"	"	4	"	"	2	"
2	"	"	2	"	"	1	"
3	"	"	3	"	"	1	"
3	"	"	1 androgynous	"		1	"

In some specimens the pistillate spikes were borne on very long peduncles overtopping the terminal, and several of these were observed to be more or less decompound.—The structure of the perigynium is very characteristic and differs essentially from that of the typical plant, which, as described by W. Boott,* is: "oval to lanceolate," "slenderly nerved, slightly serrate on the upper margins, longer and broader than the scale." The accompanying figures of the perigynia show the distinction very plainly, a distinction, however, which appears to the writer as merely varietal.

Brookland, D. C., May, 1905.

* S. Watson: Botany of California, vol. 2, p. 250, 1880.

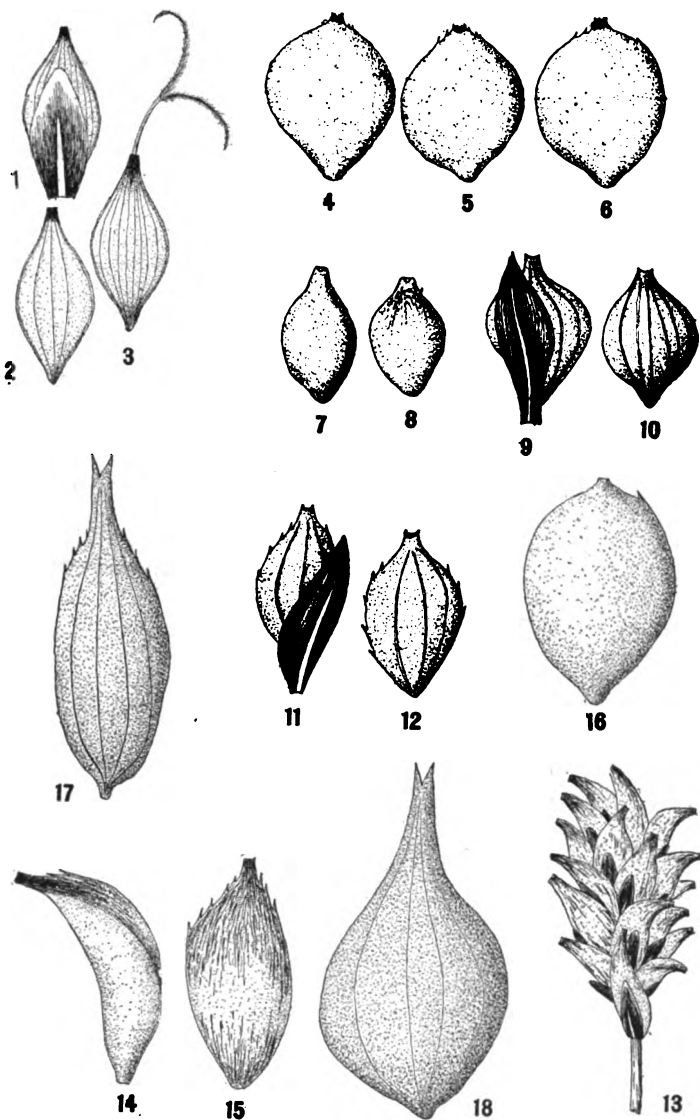


FIGURE 1. Perigynium and scale of *Carex linnaea*.
 " 2. Perigynium of same, inner face.
 " 3. Perigynium of same, outer face.
 " 4-6. Perigynium of *Carex brachypoda*, outer face.
 " 7, 8. Perigynium of *Carex pachystoma*, outer face.
 " 9. Perigynium and scale of *Carex eurycarpa*.
 " 10. Perigynium of same, outer face.
 " 11. Perigynium and scale of *Carex oxycarpa*.
 " 12. Perigynium of same, outer face.
 " 13. Pistillate spike of *Carex campylocarpa*.
 " 14. Perigynium of same, side view.
 " 15. Same, outer face.
 " 16. Perigynium of *Carex cryptoclana*, outer face.
 " 17. Perigynium of *Carex luzulaefolia*, outer face.
 " 18. Perigynium of *C. luzulaefolia* var. *strobilantha*, inner face.
 All figures magnified.

ART. XXXIV:—*Preliminary Note on some Overthrust Faults in Central New York*; by PHILIP F. SCHNEIDER.

MY attention was recently called to two unrecorded overthrusts in the limestones of this vicinity by Mr. Charles E. Wheelock, who discovered the same, and at whose request this preliminary notice has been prepared. In company with Mr. Wheelock the writer recently visited the locality and this description is largely confirmatory of Mr. Wheelock's observations, which will be given in full in a future paper.

These disturbances in the horizontally stratified Paleozoic rocks of central New York, where for so many years it was thought they could not exist and where the first announcements of such occurrences were received with such incredulity, are not yet sufficiently common to permit them to pass unrecorded. The faults are furthermore important because of the relation between them and the well known peridotite intrusives and the probability of the identity of the causes producing the same.

Both of the faults brought to light by Mr. Wheelock occur in some thinly bedded limestones which he correlates with the Bertie dolomite as described by Clarke in his recent report on the formations in the Tully Quadrangle,* or with the lower layers of the Waterlime of Vanuxem,† Geddes,‡ Schneider,§ and Luther.||

The faults can be easily studied in the gorge of Butternut Creek, near Dunlop's station, one and one-quarter miles north of Jamesville. In the east cliff, a few yards to the south of the stairs leading from Fiddler's Green to the gorge of the creek, the thrust plane of the southernmost of the faults (Fault IV. Dunlop's) can be easily distinguished as it extends upward from the base of the cliff through its entire height, a distance of nearly thirty feet. At this point the cliff is comparatively free from talus. The dip of the fault plane is 28° to the northeast, N. 40° W. This northerly dip of the thrust planes of both of the faults located by Mr. Wheelock is interesting inasmuch as they seem to belong to a series of faults extending in an east and west direction across the country, which hade to the southward.¶ It is furthermore surprising as they occur about mid-

* Bulletin 82, N. Y. State Museum, 1905, J. M. Clarke.

† Rept. 3d Dist. N. Y. 1842.

‡ Geol. Survey of Onon., Rept. N. Y. State Agricultural Society, 1859.

§ Notes on Geol. of Onondaga Co., N. Y. 1893.

|| Econ. Geol. of Onon., 15th Ann. Rept. N. Y. State Geol. 1895.

¶ This refers to the overthrusts in the Helderberg limestone series only and not to the slips and slides which are so common in or near the gypsum beds, and which can be explained by the expansion due to the formation of the gypsum, or to the solution of the gypsum or salt immediately underneath.

way between Gifford's and Russell's faults, the two disturbances showing the greatest amount of displacement and practically in a straight line with them. The layers have been sharply bent along both sides of the thrust plane and secondary crystals of calcite have been formed in the numerous fractures in and between the layers, but not as abundantly as at East Onondaga and Marcellus. Mr. Wheelock believes the amount of displacement is about four feet, but it is impossible to determine the thrust accurately because of the marked similarity of the layers of limestone.

The continuation of this fault may be seen in the west wall of the gorge, where it is not as easily accessible nor as readily studied because of the accumulated material. The bending and buckling of the layers is even more pronounced here than on the east side of the stream, although the displacement was apparently less.

Following the direction of the fault to the eastward, a cut on the trolley line just north of Dunlop's station is reached, showing some disturbance and a marked anticlinal fold. The fractured and disturbed condition of the layers in the entire cut and especially at the fold, which is directly in the line of the strike of the fault, makes it difficult to determine whether the faulting has reached upward to this point. The fracturing and shattering of the layers resembles somewhat that produced in certain of the layers overlying the gypsum, and lends color to the belief that Fiddler's Green marks the position of the gypsum deposit. A study of the gypsum ledge to the north-eastward indicates that the gypsum occurs either just above or just below the cut showing the shattered layers, while a comparison of the altitudes of the adjoining gypsum deposits shows that it should occur at the Fiddler Green locality. Nevertheless it has not yet been noted there. However, the gorge of the creek lies below Fiddler's Green, hence it is hardly possible that the faults just described can occur in the Bertie limestone which is described by Clarke as overlying the gypsum. However, according to Clarke's map the Bertie occurs in the gorge of the creek at this point.

Fault III. Dunlop's.—Following the gorge to the northward for a hundred yards or more, the folding and buckling of the layers give evidence of another disturbance. At this point the force seems to have exerted itself mainly in the bending of the layers, and without any large amount of displacement. The thrust plane of the fault is plainly visible, dipping at an angle of 23° to the northward. The displacement is not more than two feet. Fault III occurs in the same formation as that already described, the Bertie dolomite(?) The fault cannot be seen on the west side of the gorge because of a change in the

course of the stream here, which change in the direction is no doubt due in part at least to the existence of the fault right here.

Fault I. Dunlop's.—In making a cutting for Jamesville branch of the Suburban railroad about two years ago, two somewhat similar faults were exposed in the calcareous layers occurring three-eighths of a mile farther north. These layers may be continuously traced to the northeastward until they are found underlying the gypsum. They undoubtedly correspond with the limestone ledge mentioned by Clarke as containing the *Leperditia Scalaris* Jones, which occurs in the Camillus shale near the base of the Heard gypsum quarries. Inasmuch as there is only a difference of five feet in elevation between the altitude of these layers at faults I and II and faults III and IV with practically horizontal layers between the localities, it leaves little question but that faults III and IV occur in this same *Leperditia Scalaris* limestone and not in the Bertie. Fault No. I may be seen in the first cut showing the limestone, which is about 150 yards south of the crossing of the trolley and the Jamesville and Orville turnpike. The thrust plane of the fault cuts these somewhat thinly laminated layers, and dips at an angle of 35° to the south. The layers show little disturbance except at the fault line. Secondary calcite crystals occur in the fractures of the limestone, near the fault.

Fault II. Dunlop's.—Occurs in the same formation and in practically the same layers twenty yards south of fault No. I. The thrust plane dips south 32° and the layers are bent for several yards to the southward. The slickensided surfaces are well shown, also a slight tendency toward slaty fracture. Calcite crystals are lacking. The displacement is slight, probably not more than three feet. The fault maintains its character throughout the entire height of the cut. Owing to an accumulation of talus and the dense vegetable growth the faults have not been located on the west side of the stream.

Other evidences of slight faulting are noticeable farther north in this cut, also some shearing of the layers with the formation of calcite crystals.

The overthrusts now known and described in central New York are—

(a) Russell's Quarry at East Onondaga, fault plane cuts the Manlius, Lower Helderberg, Oriskany, and Onondaga formations. Displacement forty-two feet. Also shown in Hibbard's and adjoining quarries. Rocks affected for over a mile to the eastward as shown by the marked slaty cleavage in the finer grained limestones of the Corniferous.

Luther, "Econ. Geol. of Onon.," 15th Ann. Rept. N. Y.

State Geologist, 1895. Schneider "Science Series, No. 2.," Onon. Acad. Science publication, 1899.

(b) Maylie's Quarry at Marcellus, cuts Corniferous and Seneca layers of the Onondaga. Displacement, three feet. Shown in adjoining quarries for over one-half mile to westward. Thrust plane dips 17° to N. See preceding references.

(c) Gifford's Glen, two miles west of Manlius. Cuts the Onondaga and Marcellus groups. Decidedly interesting because of the remarkable manner in which the heavy layers of Onondaga limestone have been arched and bent. Thrust plane not visible. Luther makes the elevation of the limestone sixty feet, but says it is due to bending.

(d) Fillmore's Corners, one-half mile west of preceding. Cuts Onondaga and Marcellus groups. Displacement, fifteen feet. "Geological Fault at Jamesville," Schneider. This Journal, vol. iii, 1897.

(e) Indian Reservation Quarries. Two faults cut Onondaga formation. Dip 23° S. Total displacement of the several faults about six feet. Schneider, "Science Series No. IV.," Onon. Acad. Sci. 1905.

(f) Dunlop, No. I, cuts *Scalaris* limestone in *Camillus* shale. Displacement, three feet. Dip, 35° S.

(g) Dunlop, No II, *Scalaris* limestone. Displacement, three feet. Dip, 32° S.

(h) Dunlop, No. III, cuts *Bertie dolomite* (?) Displacement, two feet. Dip, 23° N.

(i) Dunlop, No. IV, *Bertie dolomite* (?) Displacement, four feet. Dip, 28° N. E.

(j) Heard's gypsum quarry. A small overthrust in the *Camillus* shale occurs here, apparently more deeply seated than the displacements so common in the gypsum quarries due to the formation and subsequent solution of the gypsum.

The writer also has MS. notes and drawings of several small faults occurring in the *Camillus* shale near the peridotite dikes which were temporarily exposed during the trenching of that region for city water.

At the Solvay quarries at Split Rock in the Manlius and Onondaga formations and in some of the adjoining abandoned quarries several sharp folds and some slickensided surfaces occur which tell of further disturbances. Similar evidences occur in Madison Co. in the vicinity of Chittenango Falls to the east of the described localities, while to the westward they may be seen in the same ledge about Auburn in Cayuga Co. Cleland* mentions a fault in the outlet of Keuka Lake, still far-

* "A Study of the Fauna of Hamilton formation of the Cayuga Lake section in central New York," H. F. Cleland, Bulletin No. 206, U. S. Geol. Survey.

ther west, but no facts are given, while the folds in the higher formations are well shown in long arch at Cayuga Lake, and similar undulations in strata at Seneca. Disturbances are also noted by Lincoln in his account of the geology of Seneca Co.*

Inasmuch as most of the above mentioned disturbances occur in or near the Helderberg escarpment, composed in the main of heavy limestones aggregating several hundred feet in thickness, and the persistence of the faults across central New York, it would seem that all are the result of some considerable force capable of affecting this entire region. In a general way the solution of the salt from the Salina formation which immediately underlies the Helderberg series has been regarded as an explanation for all the disturbances in this vicinity. Mr. Wheelock believes that the solution of all of the saline ingredients of the Salina rocks together with the slight dip of rocks of central New York is a sufficient explanation for the faulting, as any settling of the layers must shorten the length of the hypotenuse of the triangle and thus produce the force which crumpled and fractured the rocks. The fact that the softer shales sandwiched between the limestone bands are sometimes bent and sheared while the harder layers are not affected, and that the larger throws all occur in the more resistant layers, he believes will favor his explanation. This, however, would be true irrespective of the cause, provided of course that it were compression. It has also been suggested† that expansion due to the formation of gypsum would explain the faulting. While considering the causes of the faults it would be well to keep in mind that there is a series of widely known intrusives which parallel north and south this series of faults, and which extend across the state from Little Falls on the east to Ithaca on the west, and it is not impossible that both faults and dikes owe their origin to the same general disturbance. The consideration of this question, however, will be left to another paper.

Syracuse, N. Y.

* "Geol. of Seneca Co.," Rept. N. Y. State Geologist, 1894.

† E. H. Kraus, verbally.

ART. XXXV.—*Petrography of the Tucson Mountains, Pima Co., Arizona*; by F. N. GUILD, University of Arizona. (With Plate IX.)

THE Tucson Range of mountains is located directly west of Tucson and is about twenty miles long with an average width of about seven miles. It consists of a series of jagged peaks extending nearly north and south, the higher ones of which are estimated to have an altitude of 4000 feet above sea level. The approach to the main line of peaks is over a series of low-lying rounded knolls devoid of all vegetation except a few cacti and other stunted growths characteristic of an arid region.

Petrographically quite a variety of rocks are represented which are almost entirely eruptive. There occur, however, in places, remnants of the original quartzites and limestones through which this great mass of lava has broken. On the west side of the range and southwest of Tucson is an elevated plateau of an area of one hundred square miles or more, consisting entirely of these limestones and quartzites. It is quite level and the beds are exposed only along its edges and near the center where the uplifted strata form two small buttes, consisting almost entirely of crystalline limestone tilted to an angle of about forty-five degrees.

It is the purpose of this paper to describe from a petrographical standpoint the eruptive rocks without discussing their geological relations. The question of names and classification is not taken up, the writer considering descriptions of more importance. With this introduction, they will be described in the order of their relative abundance.

Rhyolite.—The main line of jagged peaks referred to above is made up of this rock, varying in color from a dark red to nearly white. Phenocrysts are inconspicuous, not very abundant and rarely exceed three millimeters in diameter. They consist of quartz and less abundant orthoclase. Under the microscope, the quartz is found to occur in rounded masses corroded by the groundmass with frequent inclusions of the latter in the form of bag-shaped inlets. Black dust-like inclusions and glass with gas bubbles are common. The feldspar, although much decomposed and containing opaque inclusions, still shows the characteristic cleavage of orthoclase. The groundmass in the darker varieties is too much altered to show any characteristic texture. In the southern portion of the district, however, material is sometimes met with of sufficient freshness to admit of satisfactory study, and here it is found to have a cryptocrystalline structure. Specimens of it are frequently found possessing faint flow lines, sometimes vis-

ible to the unaided eye, but usually requiring a microscope to be seen. (Fig. 1, Plate IX.) Occasionally dark shredded masses occur which may have been originally mica. All varieties contain irregular inclusions of varying size, sometimes two inches across, of a red jasper-like substance or of sandstone or quartzite. Frequently also rounded patches are met with which under the microscope are found to be made up of quartz and feldspar in equidimensional crystals, which may represent areas of more complete crystallization of the groundmass.

Associated with these more typical rhyolites are large masses usually of a light yellow to buff color, lacking all phenocrysts. They correspond to rocks which have been variously called felsite, felsophyre, granophyre, etc. They sometimes break with conchoidal fracture, but are more often too coarse-grained to show this characteristic. Under the microscope, quartz, feldspar and sometimes shreds of mica can be seen in the coarser varieties. The finer-grained types are made up entirely of cryptocrystalline material in which none of the constituents can be determined.

Rhyolitic Tuff.--Associated with the outflow forming the main rhyolite peaks, there were probably formed masses of volcanic ash. The greater portions of this have been washed away, but occasionally where geological conditions have been favorable some of this material has become consolidated into a compact rock of light gray color of sufficient strength to be used extensively in building. Underlying Sentinel Peak in places there are small masses of it which have been held in place by the basaltic outflow. Under the microscope it is found to be made up of fragments of quartz, feldspar, glass, etc. It is interesting to note that the quartz has the same kind of inclusions as the quartz phenocrysts in the rhyolite described above.

Andesites.--Several types of this rock varying greatly in appearance and texture occur. They may be grouped rather roughly as follows:

1. Light-colored andesites containing phenocrysts of mica or hornblende or both and of feldspar.
2. Dark-colored andesites of non-porphyrific texture.
3. Vitrophyric andesites.

The first variety covers an area only slightly less in extent than the rhyolites and constitutes the material of the low-lying knolls previously referred to. It has usually a mottled appearance not unlike that of some granites. The feldspar is pure white and the groundmass varies from white to greenish gray. The chief variation is in the black ferro-magnesian minerals, which are most often biotite, but in some localities hornblende predominates, while in still others the black phenocrysts are quite inconspicuous. Under the microscope the feldspar is clear,

usually striated, and as shown by the extinction angles on the twinning plane appears to be an acid plagioclase. The biotite is quite fresh and of the usual dark yellow-brown color. Hornblende has become darkened by alteration and is often quite opaque. The groundmass is crystalline and made up mostly of feldspar with some magnetite and shreds of the dark silicates.

The second variety is found in the northern portion of the district near the edge of the mountains about twelve miles from Tucson. It varies greatly in both megascopic and microscopic structure in different parts of the same mass. Its general appearance is more like that of a diabase except in portions where phenocrysts of feldspar appear. It is very dark with a slight green tinge weathering red. Porphyritic texture is not conspicuous and may be megascopically absent. Under the microscope, however, the rock is found to consist of crystals of plagioclase, pyroxene, and biotite in a variable groundmass. In some portions the distinction between groundmass and phenocrysts is very marked, the groundmass being typically andesitic, while in other parts there is comparatively little difference in size between the constituents of the groundmass and the phenocrysts. The pyroxene is light yellow-green in color with high extinction angle and non-pleochroic and rarely occurs in crystals longer than one millimeter. The plagioclase phenocrysts are usually somewhat larger, ordinarily clear but sometimes opaque from decomposition. The biotite appears in rather small crystals compared with the other phenocrysts and is of a light yellow-brown color with darker borders. In altered specimens the dark-colored constituents have decomposed into yellow non-pleochroic masses.

The third variety, or vitrophyric andesite, is also found in the northern portion of the district as a low rounded ridge not more than one hundred feet above the surrounding country. It is also a pyroxene mica andesite, and is distinctly porphyritic, the phenocrysts occupying fully one half of the entire mass of the rock. Black mica and feldspar are very conspicuous and occasionally orthoclase crystals eight millimeters in length showing well-formed Carlsbad twins occur. The groundmass varies from a nearly black to light gray transparent glass. Under the microscope the feldspar is found to be of plagioclase and of an unstriated variety. It frequently possesses zonal structure and is often much broken, appearing in angular fragments. The biotite is in fresh hexagonal plates and irregular shreds. Pyroxene is light green and shows high extinction angle. Magnetite is present in the usual quantities. The groundmass is isotropic and filled with what appear to be small fragments of the phenocrysts and very small crystallites.

Fine flow-lines and perlitic cracks occur in places. This variety of andesite is very common in southern Arizona and frequently possesses flow-lines of remarkable beauty. (Fig. 2.) In the upper part of the andesite the groundmass has become entirely opaque through devitrification.

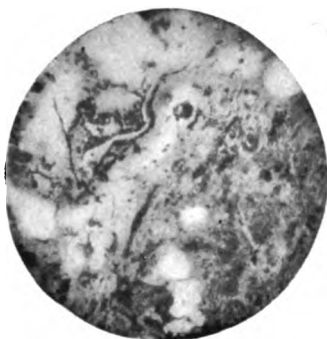
Basalt.—Outflows of this rock occur at various intervals along the edges of the mountain range especially west and south of Tucson. They vary greatly in character and may be grouped into the following varieties:

1. Fine-grained olivine basalt.
2. Porphyritic basalt.
 - a. Containing phenocrysts of feldspar and augite, in a coarse-grained or doleritic groundmass.
 - b. Containing porphyritic crystals of feldspar only in a basaltic groundmass.
 - c. Containing feldspar, augite and olivine in an andesitic groundmass.
3. Quartz basalt.

One of the most prominent of these basaltic outflows is one mile west of Tucson in the form of a symmetrical cone-shaped mass called Sentinel Peak. Immediately northwest of this is another irregular dome-shaped mass of the same rock. It is further represented in two promontory-shaped outflows southwest of the San Xavier Mission and ten miles south of Tucson. These elevations are made up chiefly of the fine-grained type of basalt in which none of the constituents can be recognized with the naked eye. It is usually compact and free from cavities, but occasionally is found quite cellular and even scoriaceous in structure. The cavities are sometimes rounded in outline with a diameter of one half inch or more, but are more often drawn out by movements of the mass when in a molten condition into irregular channels. These cavities are usually empty, but are sometimes filled with gypsum or aragonite. The predominating color is black, but deep red varieties are met with, especially in the San Xavier outflow. In places pressure and movement of the mass have developed a schistose structure, the laminations frequently being nearly vertical. This is especially noticeable on the dome-shaped mountain mentioned above near the Carnegie Desert Botanical Laboratory, and leads to the conjecture that the vent through which the basalt escaped is located under it.

Microscopically the rock is made up of numerous feldspar rods crowded together and frequently arranged in flow-lines, large amounts of magnetite and rather small quantities of olivine. Glass is present in greatly varying quantities. The olivine occurs mostly in rounded grains with a dark red halo

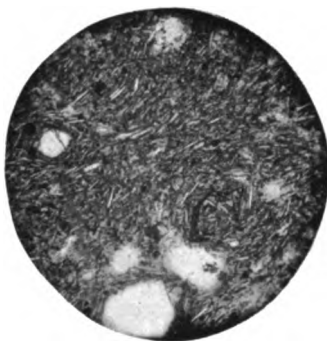
1



2



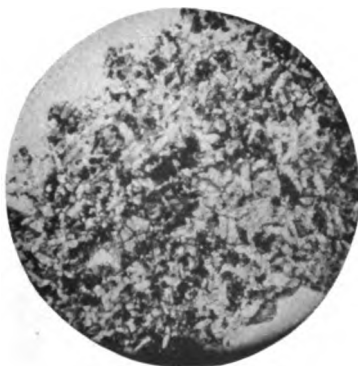
3



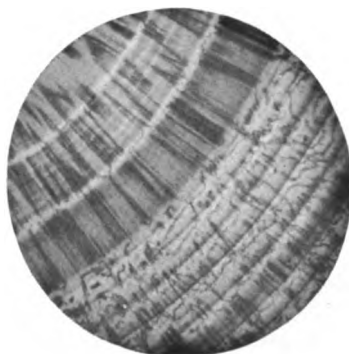
4



5



6



of ferritic material and occasionally the interior of the crystal has been reabsorbed leaving skeletons filled by the groundmass. (Fig. 3.) The accompanying illustrations (figs. 3, 4) will show the most important variation in this type of basalt. In fig. 4 the constituents are more porphyritically dispersed than is usual in these outflows and the groundmass contains more isotropic material, yet to the unaided eye they all appear nearly identical.

Porphyritic basalt of the first type (*a*) is found underlying the compact basalt of Sentinel Peak at its southern extremity. That this represents an outflow distinct from the compact variety is shown by the sharp contact between the two, where there is a layer of dark red basaltic tuff and breccia from two to six feet thick. A rock practically identical with this is found at the San Xavier Mission in a small cone-shaped elevation. This variety appears to be made up of large plagioclase crystals constituting nearly one half of the mass, and frequent black lustrous crystals of augite in a groundmass varying from coarse crystalline to compact. The feldspar crystals are sometimes over one half inch in length and frequently broken. Under the microscope they are found to be quite fresh, twinned plagioclase filled with dark inclusions of the groundmass. The pyroxene is light yellow with parallel cleavage cracks and high extinction angle. The groundmass, where it can be made out with the microscope, is mostly feldspar and augite with but small amounts of glass. Olivine is not at all abundant and in some slides is absent. (Fig. 5.)

The second type of porphyritic basalt (*b*) is found as occasional outflows south of Sentinel Peak, the largest yet observed being about seven miles from Tucson. The color of the rock is medium dark gray, and the only minerals which can be determined in it by the naked eye are feldspar and occasionally magnetite. The feldspar is rarely over one quarter inch in length and is more rod-shaped than in the foregoing type. It becomes very conspicuous only as the rock weathers. Under the microscope the feldspar is like that in the first type. The groundmass can hardly be resolved by the microscope but seems to consist mostly of feldspathic material and magnetite.

The third type of porphyritic basalt (*c*) occurs in a very small mass not more than one hundred feet in length at the southern base of Sentinel Peak. Portions of the mass are amygdaloidal and much decomposed. The amygdules are sometimes six inches in diameter and filled with agate, usually in concentric rings of varying translucency, or with calcite or siderite. Sometimes there is an outer shell of agate, the interior being filled with calcite. Geodes of brilliant smoky quartz have also been found. In places the rock is sufficiently

fresh for satisfactory study. To the naked eye the porphyritic character of the rock is not at all apparent. Under the microscope, however, it is found to be made up of distinct porphyritic crystals of abundant feldspar, considerable pyroxene, and much less olivine in a semicrystalline groundmass consisting of a felt of magnetite and dark matter which reacts feebly under polarized light.

Quartz basalt.—This unusual type of basalt is found in the extreme southern end of the mountain range as a portion of the promontory-shaped hill two miles southwest of the San Xavier Mission. The greater portion of the outflow consists of the compact basalt already described with cellular and scoriaceous modifications. On the extreme eastern slope an abundance of the quartz-bearing variety appears. Quartz is the only mineral that can be detected with the naked eye. Aside from this porphyritic constituent the general character of the rock from both a megascopic and microscopic standpoint is the same as the compact varieties described above. The quartz occurs as rounded and semi-angular grains, rarely more than six millimeters in length. Under the microscope the quartz appears clear, much fractured and quite free from inclusions of all sorts. That the quartz is primary and not due to secondary filling of cavities is inferred from the fact that the grains each consist of but one individual as shown by the extinction. This is not the case where previously existing cavities have been filled by infiltration. Amygdaloidal fillings have been observed in this same rock and they present a structure quite different from the quartz in question. Basalts containing quartz have been described by Diller,* Iddings† and Pirsson‡ from various localities in the United States, and by Andreae§ and Lacroix|| from other regions. By most of these writers their origin has been discussed and they have been held to be of primary origin. Some, like Lacroix, have, however held them to be inclusions, quartz grains caught up from lower rocks and held in the magma.

DESCRIPTION OF FIGURES, PLATE IX.

FIGURE 1.—Rhyolite, showing flow-lines in the groundmass, ordinary light, 18 diameters.

FIGURE 2.—Vitrophyric andesite, near Gila Bend.

FIGURE 3.—Basalt, Sentinel Peak, 45 diameters.

FIGURE 4.—Basalt, near San Xavier, 45 diameters.

FIGURE 5.—Porphyritic basalt, showing crystals of augite, 18 diameters.

FIGURE 6.—Agate, under polarized light, showing complicated structure, found as amygdaloidal filling in porphyritic basalt (c), 45 diameters.

* This Journal, vol. xxxiii, p. 45, 1887. Bull. U. S. Geol. Surv. 79, 1891.

† This Journal, vol. xxxvi, p. 208, 1888. Bull. U. S. Geol. Surv. 66, 1890.

‡ Bull. U. S. Geol. Surv. 139, p. 129, 1896.

§ Zeit. dent. Geol. Gesell, 1892, p. 824.

|| Enclaves des roches volcaniques, Ann. Acad. Macon, vol. x, 1893, p. 17.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Gases produced by Actinium.*—It is known that solutions of radium salts give off continuously a mixture of hydrogen and oxygen from the decomposition of water, and it has been found that this detonating gas contains a small quantity of helium which is believed to be a product of the disintegration of the radium atom. DEBIERNE has recently confirmed this behavior of radium by using nearly a tenth of a gram of Curie's radium bromide and operating in a manner similar to that of Ramsay and Soddy. He has found, further, that solutions of actinium salts give off detonating gas containing helium, and that the amounts of these products apparently correspond to the amounts produced by a quantity of radium having the same activity.

For the experiments with actinium he used the whole of his most active products, and obtained the same results with a portion which had been specially purified from any possible contamination with radium by adding to it barium chloride and removing the barium. It was found, moreover, that the barium thus removed did not contain an appreciable quantity of radium. It was found also that solid actinium fluoride gave off helium. Debierne states that in addition to the large quantity of emanation with a rapid rate of decay which is given off by solid salts of actinium, there comes from it a very small quantity of an emanation of much slower change which he has identified as identical with the radium emanation; but its quantity is too small to have produced the helium found in his experiments.—*Comptes Rendus*, cxli, 383.

H. L. W.

2. *A New Heavy Solution.* — DUBOIN has prepared some liquids analogous to the well-known Thoulet's solution, one of which, at least, appears to possess decided advantages over the latter. In the place of the potassium iodide used by Thoulet, he uses sodium or lithium iodide. The alkaline iodide and mercuric iodide are alternately added to a small quantity of water until saturation takes place, the temperature being slightly raised at the end of the operation. Then the liquid is allowed to cool, and after twenty-four hours it is filtered. It was found that Thoulet's solution prepared in this way, and filtered at 22·9°, gave a specific gravity of 3·196 and an index of refraction of 1·780, while the sodium mercuric iodide solution, filtered at 24·75°, gave a density of 3·46 and an index of refraction of 1·797. The lithium solution is intermediate in its density and refraction between the two just mentioned. Analyses of the solutions showed that their compositions corresponded closely to the formulas K_2HgI_4 , Na_2HgI_4 , and Li_2HgI_4 , and in each case the amount of water present was somewhat more than 10 per cent. A similar ammonium mercuric iodide solution was prepared, but this was less dense than Thoulet's liquid.

The sodium mercuric iodide solution is of considerable interest, as it is heavier than even methylene iodide. Although water produces in it a precipitate of mercuric iodide, it dissolves without change in alcohol and many other organic liquids.—*Comptes Rendus*, cxli, 385.

H. L. W.

3. *Hydrolysis of very Concentrated Ferric Sulphate Solutions*.—It has been observed by RECOURA that a concentrated solution of ferric sulphate made by dissolving the anhydrous salt in its own weight of water is completely decomposed when it is placed in contact with acetone for several days. The products are sulphuric acid, which dissolves in the acetone, and a basic ferric sulphate which separates in the solid form. The latter is yellowish white in color, is soluble in water, and has a composition represented by the formula $6\text{Fe}_2(\text{SO}_4)_3 \cdot \text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$. The same solid is formed without the use of acetone when a strong solution of ferric sulphate is placed in a well-stoppered flask and allowed to stand for a longer time. With solutions of the strength given above, the deposit begins to form after about twelve days and extends through the liquid in about a month. With stronger solutions the precipitate is formed more rapidly and abundantly, while with solutions slightly more dilute no basic salt separates. The deposit is formed most rapidly at 20° , and more slowly as the temperature is kept lower.—*Comptes Rendus*, cxl, 1685.

H. L. W.

4. *Separation of Gold from the Metals of the Platinum Group*.—JANNASCH and VON MOYER have found that gold is precipitated quantitatively by a salt of hydrozine in any kind of solution. This reagent, however, on account of its powerful reducing action does not serve to separate gold from the metals of the platinum group, although it is thus separated satisfactorily from potassium, sodium, barium, strontium, calcium, magnesium, aluminium, chromium, zinc, manganese, iron, uranium, nickel, cobalt, cadmium, mercury, lead and copper. Gold is precipitated by a hydroxylamine salt in acid solution somewhat slowly, and not below a temperature of 80° . Preliminary tests indicate that hydroxylamine hydrochloride is a satisfactory reagent for the separation of gold from palladium, platinum, iridium and rhodium, as well as from ruthenium and osmium.—*Berichte*, xxxviii, 2129.

H. L. W.

5. *Determination of Sugar with Fehling's Solution*.—On account of difficulties encountered in determining small quantities of sugar by Fehling's volumetric method, LAVALLE has modified this by carrying it out in the presence of an excess of caustic soda, so that the cuprous oxide produced remains in solution, and the change in color is more readily detected. The operation is as follows: In a porcelain dish of 200°C capacity are placed 5 or 10°C of Fehling's solution, 30°C of sodium hydroxide solution (1:3), and 50 or 60°C of distilled water. The liquid is then heated, and when it begins to boil the solution to be tested is gradually added. The operation is finished when the last drop causes the blue color of the Fehling's solution to disappear.—*Berichte*, xxxviii, 2170.

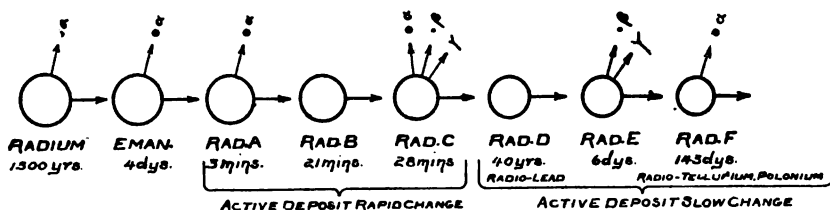
H. L. W.

6. *Slow Transformation Products of Radium.*—An article by Prof. E. RUTHERFORD, in the September number of the Philosophical Magazine, closes with the following summary of the products recognized in the slow transformation of radium.

“The results of the comparison of the products of radium with those contained in polonium, radio-tellurium, and radio-lead are summarized below.

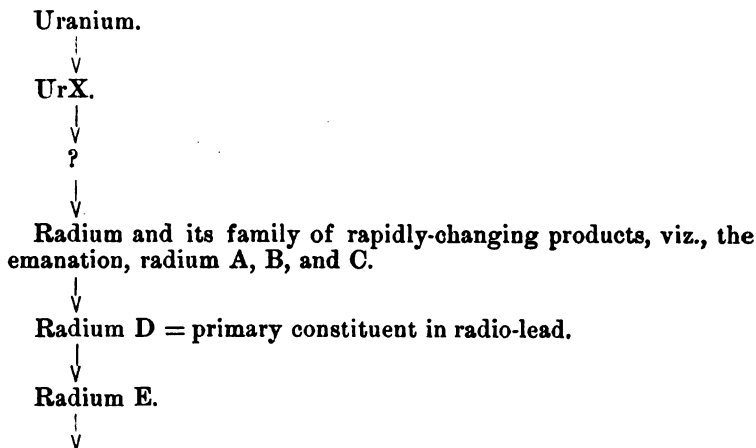
Products in old Radio- lead.	{	Radium D = product in <i>new</i> radio-lead, no rays. Half transformed in 40 years.
		Radium E = gives out β rays, separated with bismuth, and iridium. Half transformed in 6 days.
		Radium F = product in polonium and radio tellurium. Gives out only α rays. Half transformed in 143 days.

The family of substances produced by the disintegration of radium, together with the time for each to be half transformed, is shown diagrammatically in the figure.



It is now fully established by the researches of Boltwood, Strutt, and McCoy that the amount of radium present in radioactive minerals always bears a constant ratio to the amount of uranium. The investigations of Boltwood, in particular, have shown a surprisingly good agreement between the content of radium and uranium for minerals obtained from various localities, which differ very widely in their content of uranium. This proportionality is a strong indication that radium is produced from uranium; and a conclusive proof of this point of view is given by the experiments of Soddy and Whetham, who find that there is a slow growth of radium in uranium which was initially freed from radium. In addition, the actual amount of radium in radioactive minerals is of the right order of magnitude to be expected from theoretical considerations, if uranium is the parent of radium.

Soddy finds that the present growth of radium from uranium is only a very small fraction of the theoretical amount. This is most simply explained by supposing that one or more products of slow period of transformation intervene between UrX and radium. The uranium-radium family and their connection with one another is summarized below.



Radium F = active constituent in radio-tellurium and polonium.

No evidence has been obtained that any further active products exist after radium F has been transformed. If the α particle is a helium atom, remembering that five products are present in radium which emit α particles, the atomic weight of the transformation product of radium F should be $225-20$ or 205 . This is very close to the atomic weight of lead, 206.7 . The view that lead is the final or end product of the transformation of radium is supported by the fact that lead is always found in the radioactive minerals in about the amount to be theoretically expected from the content of uranium, when the quantity of helium, present in the mineral, is used to compute its probable age.* A similar suggestion has recently been advanced by Boltwood."

II. GEOLOGY AND MINERALOGY.

1. *Indiana, Department of Geology and Natural Resources, Twenty-ninth Annual Report*, W. S. BLATCHLEY, State Geologist, 1904. 888 pp., 34 pl.—This Twenty-ninth Report of the State Geologist of Indiana is largely devoted to the economic interests of the state, which have shown a very large increase in recent years. Thus comparing the figures for 1895 with those for 1904, although there has been a falling off in natural gas, the amount of coal produced has been more than doubled and that of petroleum increased nearly three times, while the value of the output of building stone and of clay products has also doubled. Twenty-five years since the resources of the state were almost exclusively agricultural, while in 1904 the total value of the mineral resources amounted to not less than forty million dollars. The present volume discusses very fully the clays and clay industry of the

* A full discussion of this question was given by the writer in the Silliman Lectures, Yale University, March, 1905.

state, in which direction the state has been found to be very rich, the shales, particularly those of the Coal Measures, which were not many years since supposed to be valueless, now being turned on an extensive scale into pipes and tiles, bricks of various kinds and other products. An account is also given of the petroleum industry, and the volume closes with an illustrated chapter upon the insect galls of Indiana by Melville T. Cook.

2. *Geological Survey of Louisiana*, G. D. Harris, *Geologist-in-charge*.—It is announced that hereafter the biennial reports of the State Survey of Louisiana will be brought out first as Bulletins and subsequently will be bound up in part as regular volumes. Of the Report of 1905, three Bulletins have already appeared: No. 1—The Underground Waters of Louisiana; No. 2—Magnetic Survey of Louisiana; and No. 3—Tide Gauge Work in Louisiana. These may now be had gratis by addressing Dr. W. R. Dodson, Director Experiment Station, Baton Rouge, La.

3. *Geological Survey of New Jersey. Annual Report of the State Geologist, Henry B. Kummel, for the year 1904.* 317 pp., 19 plates, 18 text figures. Trenton, 1905.—This report contains a popular account of fossil fishes and their place in paleontology, by Dr. C. R. Eastman, followed by a detailed account of the fossil fishes of the Triassic as found in the Newark formation. Dr. Weller contributes papers on the faunas and corresponding formations of the Cretaceous of New Jersey. Professor F. B. Peck has a chapter on the talc deposits of Phillipsburg, N. J., and Easton, Pa., while the molding sands are treated by H. B. Kummel and S. H. Hamilton. Progress is noted in the survey of the pre-Cambrian rocks in coöperation with the United States Geological Survey, and further parts treat of well records, forest fires and mining. The work throughout the report is thorough and of high grade; it deals largely with subjects of practical value to the state.

J. B.

4. *Brief descriptions of some recently described Minerals*.—BECKELITE is a silicate of the cerium metals and calcium, described by J. Morozewicz and named after Prof. Fr. Becke of Vienna. It is found in a rock of the eleolite-syenite type, called by the author mariupolite and forming one of the petrographic elements of the Azov granite table. It occurs in coarse grains of a light yellow color, optically isotropic, also in octahedrons and dodecahedrons resembling pyrochlore. The hardness is 5 and the specific gravity about 4.15. An analysis yielded:

SiO₂ ZrO₂ + R₂O₃ Mn₂O₃ CaO MgO K₂O Na₂O ign.
17.13 65.31 0.07 15.46 tr. 0.39 0.78 0.99=100.13

The rare elements forming the 65.31 of ZrO₂ + R₂O₃ included the following: ZrO₂, 2.50, Ce₂O₃, 28.10, La₂O₃, 13.60, Di₂O₃, 18.00, Y₂O₃ + Er₂O₃, 2.80, Al₂O₃, 0.30, Fe₂O₃, tr. The calculated formula is Ca₂(Ce, La, Di), Si₂O₆.—*Min. petr. Mitth.*, xxiv, 120, 1905.

Several new species are described by R. H. Solly, in a recent number of the Mineralogical Magazine (xiv, 72). They are

derived from the dolomite of the quarries in the Binnenthal, Switzerland. **HUTCHINSONITE**, named after Dr. Arthur Hutchinson, of the University of Cambridge, is a species occurring in prismatic orthorhombic crystals, with numerous terminal faces. The color is gray to grayish black, and the streak vermilion. The crystals are transparent to nearly opaque. Hardness, 1.5-2; cleavage, good, parallel to the macropinacoid. In composition it is found by G. T. Prior to be a sulpharsenite of thallium, lead, silver and copper; it contains nearly 20 per cent of the rare element thallium.

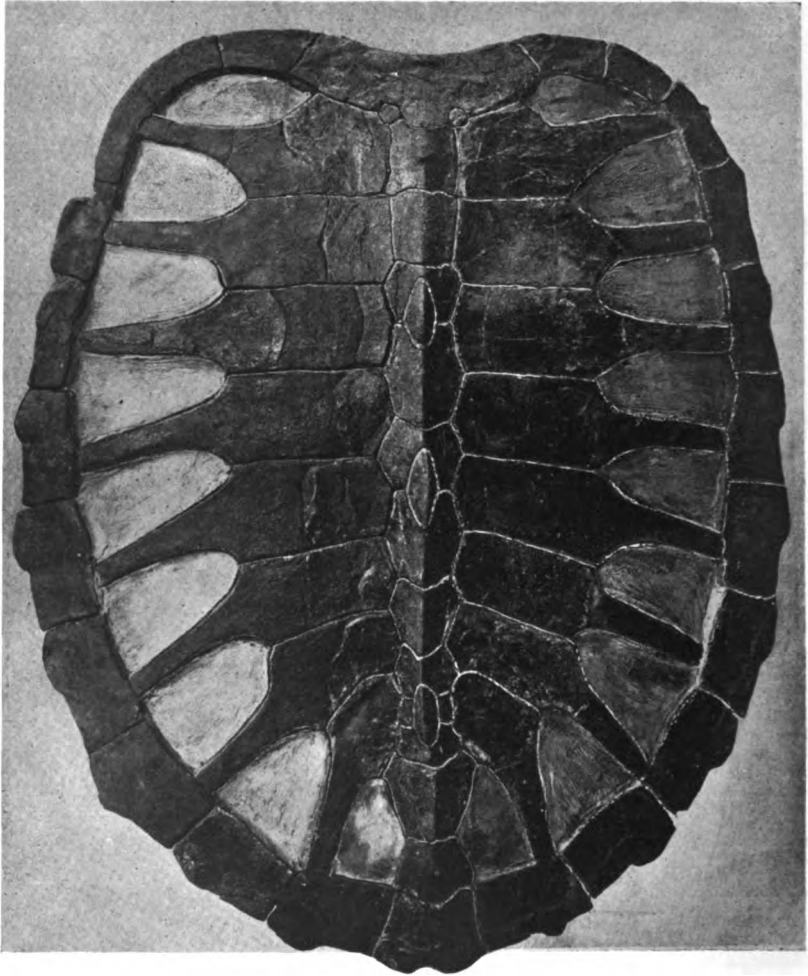
SMITHITE, named after Mr. G. F. Herbert Smith of the British Museum, occurs in monoclinic crystals, resembling flattened hexagonal prisms, with prominent basal plane. The lustre is adamantine, the color light red, and the streak vermilion. The crystals are transparent to translucent. Hardness, 1.5-2; cleavage, parallel to the orthopinacoid, perfect. The surface of the crystals changes on exposure to light from pure red to orange red. According to G. T. Prior, the composition is expressed by the formula AgAsS_3 .

TRECHMANNITE, after Dr. C. O. Trechmann, occurs very sparingly in minute rhombohedral crystals resembling the two species hutchinsonite and smithite in color, streak and hardness. The crystals showed portions of hexagonal prisms, with small pyramidal and rhombohedral faces. Cleavage was observed perpendicular to the prism. The composition is as yet undetermined.

MARRITE, named after Dr. John Edward Marr of Cambridge, occurs in highly modified monoclinic crystals, usually doubly terminated. The color is lead- to steel-gray, the surface showing iridescent tarnish; the luster is metallic, brilliant. The hardness is 3 and the fracture conchoidal; no cleavage was observed. Only a single specimen had been found at the time the description was published; this showed some fifteen small crystals implanted upon the dolomite, hence though the crystallographic data are complete the composition is yet to be determined.

LENGENBACHITE, named after the Lengenbach, a tributary stream in the Binnenthal, occurs in bladed crystals often very thin and sometimes curled up like paper. They show a highly perfect cleavage and splendid luster; the crystals are apparently twinned and are inferred to belong to the triclinic system. The plates are flexible and somewhat malleable but not elastic. The color is steel-gray, often with iridescent tarnish, the luster metallic; the specific gravity is 5.80. In composition it is essentially a sulpharsenite of lead with small amounts of antimony, silver and copper, as determined by A. Hutchinson.

BOWMANITE, named after H. L. Bowman of the University of Oxford, occurs in rhombohedral crystals with basic cleavage and having the form of six-sided plates, often grouped in rosettes; the crystals show a pseudo-symmetry in the basal sections. The color is honey-yellow, the luster brilliant vitreous to resinous. The hardness is 4.5, the specific gravity 3.2. According to Bowman it is essentially a phosphate of lime and alumina with small amounts of iron, water and possibly magnesia.



Carapace of *Toxochelys Bauri* Wieland sp. nov. from the Niobrara Cretaceous of Gove County, Kansas, as partly restored and mounted in the Yale Museum.—Actual length about 53^{cm}.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXVI.—*A New Niobrara Toxochelys*;* by G. R. WIELAND. (With Plate X.)

NONE of the numerous marine, or semi-marine turtles from the Kansas chalk or Niobrara Cretaceous have proven of greater interest than the forms included within the genus *Toxochelys*. For this wholly extinct American group unites carapacial and plastral characters of the *Lytolomas* of the Upper Cretaceous of New Jersey with *Chelydra*-like cranial features, and is well represented by a considerable number of specific forms and variations presenting fairly clear evidence that we have here to deal with a line which independently acquired the modifications of limb structure suiting at least some of its members to a marine habitat.

Moreover it is very significant that discrete epi-neural ossicles somewhat similar to those the writer supposed might be present in *Archelon* are borne serially either on the neuralia, or over the neural junctions in an order suggesting that they have an ancient history, possibly analogous to the ossicles of somewhat similar form so characteristic of the Crocodilidæ and in part the Chelydridæ. These ossicles as noted further on were first observed in *Toxochelys (serrifer) stenoporis* by Case (2) and later more fully described and commented on by Hay (6, 7, 8). The character of the entire series is, however, now determined for the first time. The idea that such ossi-

* The writer's previous contributions, mainly on the marine turtles, are as follows:—

This Journal, vol. ii, Dec., 1896, pp. 399-412, pl. VI. American Naturalist (p. 446), 1897. This Journal, vol. v, Jan., 1898, pp. 15-20, pl. II; vol. ix, Apr., 1900, pp. 237-251, pl. II; vol. ix, June, 1900, pp. 413-424; vol. xiv, Aug., 1902, pp. 95-108; vol. xv, March, 1903, pp. 211-216; vol. xvii, Feb., 1904, pp. 112-132, pls. I-IX; vol. xviii, Sept., 1904, pp. 183-196, pls. V-VIII.—(In Press,—Protostega; Memoirs, Carnegie Museum of Pittsburgh; Plastron of Protosteginæ.)

AM. JOUR. SCI.—FOURTH SERIES, VOL. XX, NO. 119.—NOVEMBER, 1905.

cles really represent a disappearing series of dermal elements is further strengthened by the writer's observation that interpolated ossicles also occur in the marginal series of occasional specimens of *Lytoloma angusta*, as will be further considered below.

Despite the frequent occurrence of *Toxochelyds* in the Niobrara, until now no complete carapace has been described. It is, therefore, of timely interest that a specimen collected by Mr. Charles H. Sternberg in Gove County, Kansas, and very recently acquired by the Yale Museum, includes a carapace and plastron sufficiently complete to determine accurately all the details of shell structure and form. The original locality, according to Mr. Sternberg, is in a ravine about three miles north of Monument Rocks, and about four miles east of the western Gove County line. This fossil is numbered 2823 in the Yale Museum accession list, and on the basis of the analysis given below is referred to the new species *Toxochelys Bauri*, in honor of that distinguished student of the Testudinata the late lamented Professor Georg Baur. As shown on Plate X, *T. Bauri*, represents one of the most ornate of all extinct Testudinate species. The type consists in the following elements:—

The nuchal and eight closely articulated neuralia with the ninth median or post-neural element bipartite, and followed by an antero-pygial and the pygal marginal (the postero-pygial being the only median element absent); three epi-neural ossicles respectively seated on the 3d and 4th, the 5th and 6th, and the 8th–10th members of the neural series; the 1st–3d, and the 8th–11th right marginals; the 4th–6th, 8th and 10th left marginals; most of the pleuralia; also the right hyo- and hypoplastron nearly complete, and various fragments of vertebræ with several centra and arches. Of the right pleuralia the first and seventh are complete, and the third, fourth and sixth only lack rib-tips, while the expanded plates of all the right pleurals but the distal portion of the fifth, are fortunately present. On the left side the pleurals are not so complete, only the proximal ends having been recovered, with the exception of the third, which only lacks a middle portion of the plate. Cf. figure 6.

The hyo- and hypoplastron lack their interior digitations, but fortunately permit an approximate restoration from what is known of the plastron of several other species (cf. figure 7). The fragmentary or not directly determinable skeletal parts include two dorsal centra, 4^{cm} in length, and several caudal centra, with a few portions of cervicals.

With the exception of some of the middle and anterior marginals, which are curiously crushed from very different

angles, the various elements of the present in reality exceptionally fine fossil do not appear to have been much displaced in their original chalk matrix. This had been removed, however, and aside from the neurals, which remained for the greater part solidly articulated, any clues to form and organization afforded by position in the matrix had been thus destroyed before the specimen reached the Yale Museum.

Despite this crushing and dissociation of parts, as the result of a careful joint examination by the Museum preparateur, Mr. Gibb, and the writer, it has nevertheless proven possible for the former to make a very handsome and successful mounting of the fine carapace with the considerably restored plastron in its approximately natural position, as illustrated on Plate X, and figures 1-3, and 6, 7. In fact it is owing to the presence of the nearly complete hyo- and hypoplastron that we are enabled to determine the true width of the carapace, which is indicated in the corrected drawing (figure 1) based in part on the measurement thus obtained. The specimen itself is mounted more nearly as removed from the chalk matrix, the width being somewhat exaggerated by compression. For it was at once decided that it would be far better in mounting the specimen to adhere nearly to the form that had resulted from crushing in the matrix, rather than to distort the junctions of the several elements in an effort to reach the elongate form *Toxochelys Bauri* really had. The restoration is accordingly, although at first sight indicating a considerable length of shell, not nearly so narrow and relatively long as originally in life,—an interesting fact because this is almost the only marine form with a carapace suggestive of the great length seen in *Dermochelys*.

Description of Parts.

As the main features of the anatomy of the carapace appear in sufficient detail in the summary of characters and measurements given below, taken in conjunction with the accompanying figures and plates, we may pass on to a discussion of the special or unique features of interest, namely the *nuchal*, the *epi-neural spines*, and the *pygal region*.

Nuchal.—The Trionychid-like fontanelles at the junction of the nuchal, first neural and pleurals (figure 1, *f*), are circular to slightly elliptical, and 1^{cm} in diameter. Such have not been hitherto observed to occur outside the Trionychids, and with the general form of the nuchal suggest a certain connection with original lines less distant from the Trionychid stocks than are the Cheloninae. Elsewhere the writer has suggested that the Nuchal and Epiplastra of *Dermochelys*, *Protostega*, and the *Jurassic* *Thalassemyds* may go to indicate a yet

closer relationship to stocks ancestral to the Trionychidæ, and that there are many most suggestive indications that indepen-

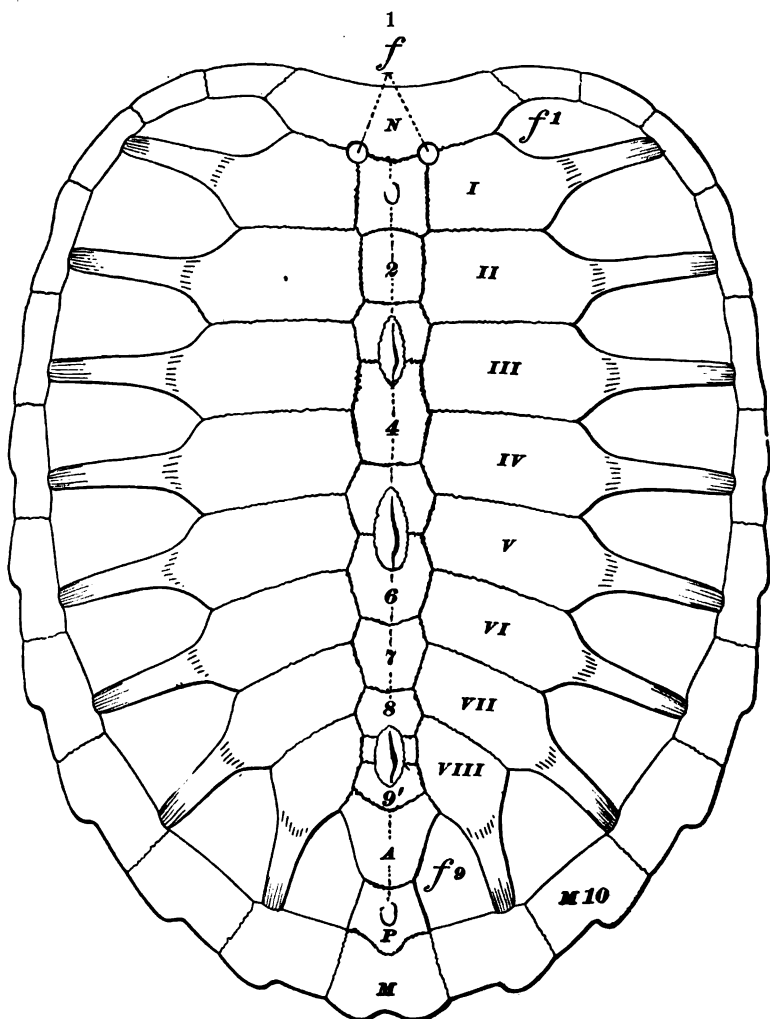


FIGURE 1.—Carapace of *Toxochelys Bauri* Wieland, $\times \frac{1}{4}$ nearly. (Drawn from type.) *N*, Nuchal; 2, 4, 6, 8, Neuralia; 9', posterior segment of the 9th or post-neural element of the median series; *A*, Antero-pygals; *P*, Postero-pygals; *M*, Marginalo-pygals; I–VIII, the Pleuralia; *M10*, 10th (rib-free) Marginal; *f*, the post-nuchal foramina; *f*¹, *f*⁸, 1st and 8th pleuro-marginal fontanelles. The three Epi-neurals are not lettered.

dent marine races of Testudinates, of which at least a half dozen may be enumerated, have been repeatedly developed ever since the Jurassic.

It is also of much interest that while in forms like *Osteopygis* a nether nuchal process is wholly absent, there is in the present turtle a mere, although distinct beginning of such a

2

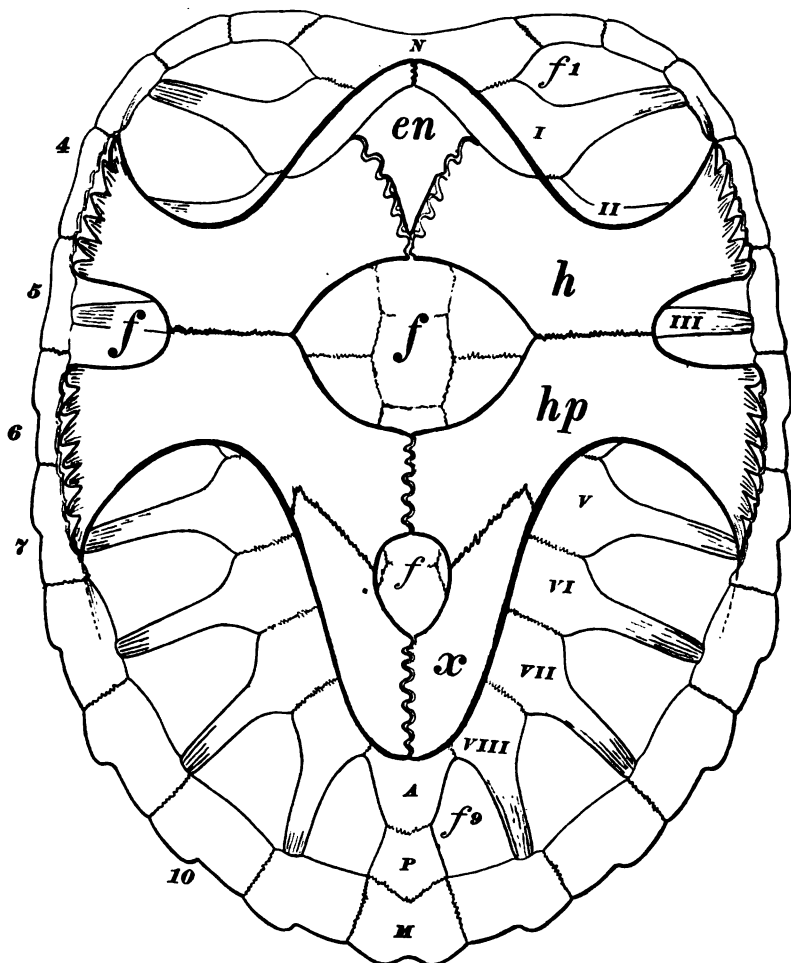


FIGURE 2.—Plastral view of *Toxochelys Bauri* Wieland, $\times \frac{1}{4}$ nearly. (Drawn from type).—*en*, Entoplastron; *h*, Hyoplastron; *hp*, Hypoplastron; *x*, Xiphiplastron; *f*, *f*, *f*, the median and the lateral hyo-hypoplastral, and the hypo-xiphiplastral foramina; 4-7, the plastron-supporting marginalia. Other letters as in figure 1.

process, and in *Toxochelys latiremis* a much larger projection for actual cervical articulation. This process thus appears to have arisen in different groups rather than to have been com-

monly present in Cretaceous turtles, and may now be considered to have been definitely traced to its origin in at least one genus.

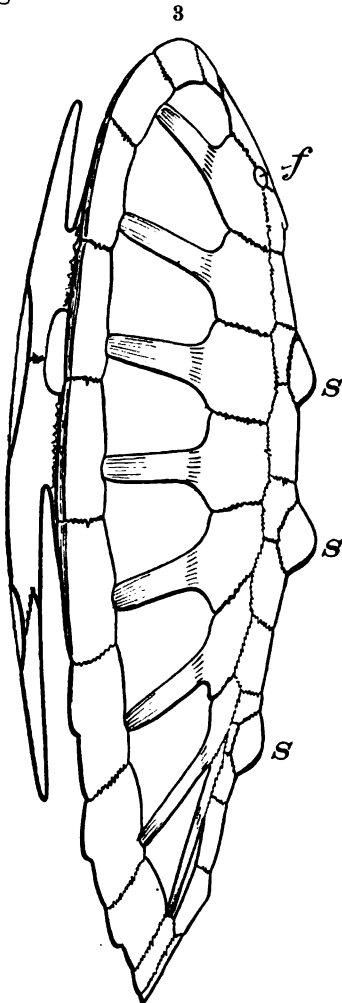


FIGURE 3.—Lateral view of the Carapace of *Toxochelys Bauri* Wieland, $\times \frac{1}{4}$ nearly. Drawn from the type. *s, s, s*, the three Epi-neural spines supported respectively by the 3d and 4th, the 5th and 6th neurals, and the 8th neural and the post-neural elements; *f*, the post-nuchal foramina.

Epi-neural Spines—The series of epi-neural spines taken in conjunction with the strongly carinate neurals, and the keeled marginals, give to the present fossil carapace a most ornate form. See figures 1 and 3.

The earliest suggestion of the possible presence of epi-neural elements in the Testudinata was made by the writer in his original description of the Fort Pierre Cretaceous turtle *Arche-lon* given in this Journal for Dec., 1896. It appears on page 400 of that number as follows: "One of the chief features of the carapace is the arching into a heavy dorsal ridge, beginning just back of the region of the first dorsal vertebra, and from thence continuous, except in the sacral region. It marks the position of the neural spines and is very distinctly grooved from anteriorly to the region of the eighth dorsal vertebra. Immediately over the neural spines this groove inclines to widen and send out asteriations. In life these grooves were no doubt filled with horny material, and the animal *may have borne a dorsal row of spines.*"

Two years later the spines of *Toxochelys* were first observed by Case,* and have been since more fully described and commented on by Hay, who would see in them the remnants of a former dermal series, probably once common to all turtles, and going far to explain the homol-

* Kansas Univ. Geol. Survey, vol. iv, p. 382 (1898).

ogy of the osteodermal mosaic of *Dermochelys* (6, 7). The present is, however, the first time that the entire series of ossicles and their relation to the successive neurals has been determined. As may be judged from reference to the several figures, the system of ossicles may really be a much changed and disappearing one. The first neural bears a small but very distinct completely fused boss near its middle, and then forms the beginning of the dorsal carina. The third neural which is rather short, and the fourth which is abnormally long, support a large epi-neural spine. This occupies all the median posterior three-fourths of the length of the third and the anterior fourth of the length of the fourth neurals, and is doubtless the second member of the original epi-neural series. The second free epi-neural [or third of the original series] is the largest, and is equally borne by the fifth and sixth neurals. The third free epi-neural [or fourth of the hypothetical primitive series] rests over the ninth member of the neuralia, so as to project slightly forward onto the eighth and well backward over all the anterior half of the post-neural tenth. This latter epi-neural is the smallest of the three free epi-neurals.

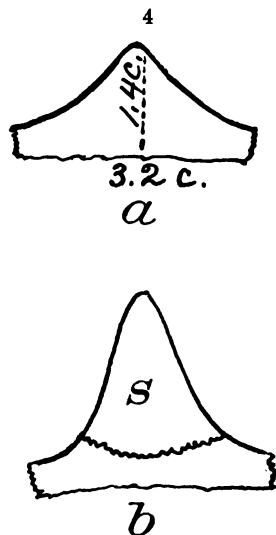


FIGURE 4.—*Torochelys Bauri* type, $\times 1/1$. *a*, Vertical transverse section through the second neural showing the average elevation and outline of the median neural carina. *b*, Vertical transverse section through anterior end of the 6th neural, and the epi-neural spine (*s*) borne on this and the 5th neurals.

Whether a fifth member of the epi-neural series was borne by the postero-pygial, which would afford the symmetrical position, is of course conjectural in the absence of this latter member of the median series.

Whether or not the keels of the marginalia mark the fusion of a lateral series of elements, corresponding to the epi-neurals, is likewise only conjectural, although it appears that some light may be shed on the subject by *Proganochelys*. There is however some uncertainty as to the number of marginals and true significance of the peculiar marginal fringe of spines in this singularly interesting turtle as so carefully studied by Fraas (4) from material recovered under conditions unfavorable to the exact preservation of structural details. But it is also a most interesting and suggestive fact that small ossicles are irregularly interpolated between the lateral marginals of the Cretaceous *Lytoloma*, as small triangular elements about 1.5^{cm} on each side. Such are shown at E, E, E in the accompanying figure 5. As these epi-marginal ossicles are not equally present on both the right and left marginals even in the same individual and certainly not always present in all specimens of *Lytoloma angusta*, they would at first sight appear to be of much less significance, taken by themselves, than are the epi-neurals of *Toxochelys*. Nevertheless it would now seem that they do represent a disappearing series that may once have invested the entire margin of the carapace. If so, they form one of the most impressive examples of the very last vestiges of a vanishing series.

The truth of this hypothesis yet remains to be mainly determined by fossil evidence, which we may hope ere long to discover, if correct. At any rate it is extremely interesting and suggestive to find further traces of an additional osteodermal series in *Lytoloma*, whatever may be the homology to that of *Dermochelys*.

What the characteristic number of elements in this system as developed in pre-Cretaceous testudines was, no one has yet attempted to suggest. Nor is it possible to reach a safe conclusion in the absence of further paleontologic evidence. It would appear however that the series was once at least as complex as is the horn-shield and the bony plate series, and that it had some form of alternate or imbricate relationship to both these latter systems. Also, if the osteodermal mosaic of *Dermochelys* arose from such an additional dermal series, such origin must therefore have been in part by a subdivision process such as was suggested to Baur by the abnormal breaking up into smaller ossicles along the edges of the pleurals observed by him in *Eretmochelys*. Such a subdivision would of course follow the lines of the original system, and could thus very well produce the carapacial carina seen in *Dermochelys*.

It should be especially noted in this connection that such an hypothesis for the more primitive origin of the osteodermal mosaic does not necessarily imply a more ancient origin for

Dermochelys than for the Cheloniidæ, and that its correctness would not necessarily leave *Dermochelys* the most primitive of turtles, but rather the most specialized, as hitherto held by Baur, Dollo, and the writer. As stated, only new fossil evidence can settle the very interesting questions that here arise.

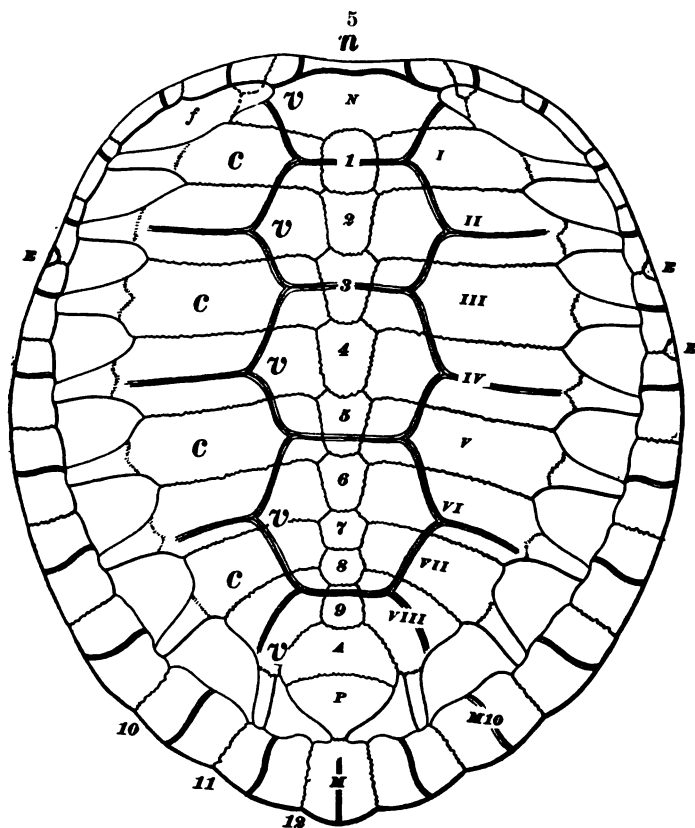


FIGURE 5.—Carapace of *Lytoloma angusta* from the Upper Cretaceous Greensand of Barnsboro, Gloucester Co., New Jersey. E, E, E, Epi-marginals respectively borne by the right 4th and 5th, 5th and 6th, and the left 4th and 5th marginalia. (Enough marginals are present in the original specimen—No. 625 of the Yale Collection—to determine that no further epi-marginals accompanied these three, unless such were borne anteriorly to the 4th marginals.) Epi-marginals are not always present in *L. angusta*.

The pygal region.—The neural series of *Toxochelys Bauri*, excluding of course the epi-neural ossicles, agrees with that of *Hardella thurgi* (1) in having ten elements, in the neural row, —in reality an interpolated element between the normal or

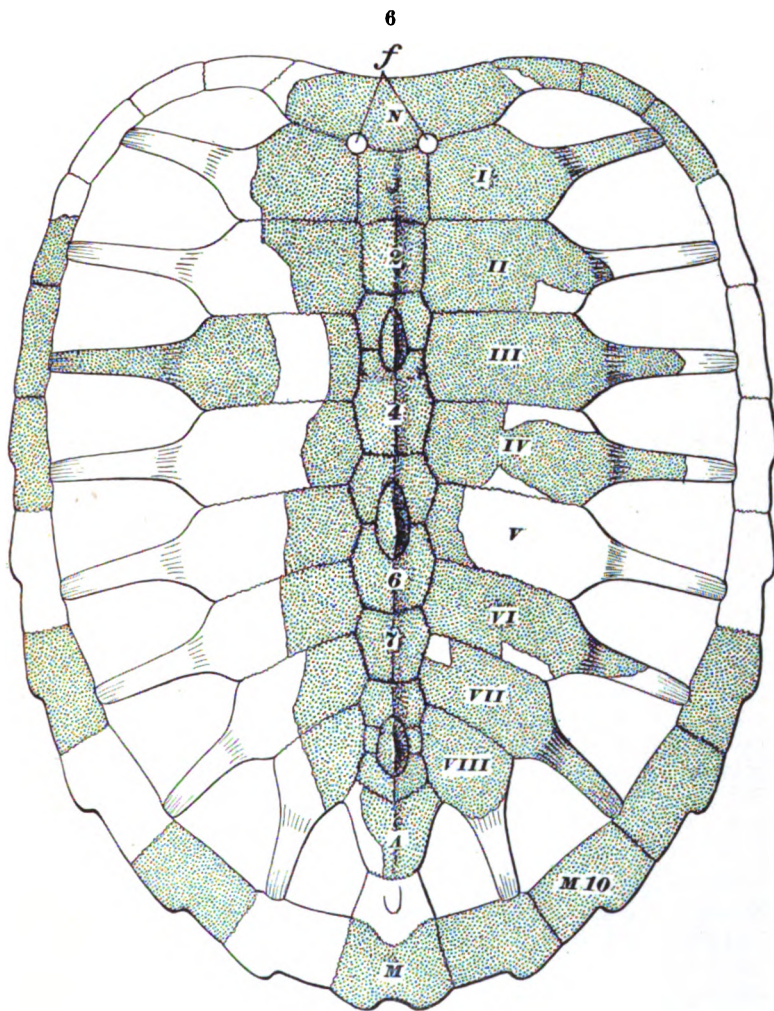
common eighth and ninth elements, or better a division of the ninth or post-neural region of the median series. Unlike *Hardella*, however, the pygal is not single, the post-neural region being divided into an antero- and postero-pygal, as in *Osteopygis*, and in the Cheloninæ. The existence and outlines of the postero-pygal are indicated by the conformation of the pleuralia and posterior marginals, together with the posterior suture of the antero-pygal and the anterior suture of the pygal marginal, which are quite unlike. From these sutural borders it is also quite evident that the heavy median keel which evenly traverses all the length of the antero-pygal, finally ran out on the postero-pygal, where it no doubt ended as a distinct boss like that of the first neural, which would perforce represent a fused fifth member of the median or epi-neural ossicular system. The pygal marginal, in correspondence with the strong keels of the marginals, is ornately double-keeled. The organization of this region has not hitherto been determined in any species of *Toxochelys*. Both Case (2) and Hay (6) have figured the posterior half of the carapace of *T. (serriifer) stenoporus* type, but without determining the sutures, whether because not indicated or because of difficulty of interpretation not being stated by either. A distinct difference from the present specimen is, however, obviously present in the postero-pygal region.

Synopsis of the Characters of Toxochelys Bauri (type).

Carapace.—Elliptical to elongate in outline with large and persistent pleuro-marginal fontanelles; composed of 52 bony plates and 3 additional epi-neural spinose ossicles; numerical arrangement of parts combining the general alignment and form seen in the Chelonine *Lytoloma angusta* with the post-neural arrangement of the existing *Hardella thurgi*. Surface finely granulate to smooth, and horn-shield sulci not apparent, save for notches formed by the posterior border of the marginal keels. (A distinctly leathery hide is not, however, supposed to be present.) Marginals, 11 pairs, rather narrow anteriorly, increasing very slowly in breadth to the 11th, which is still nearly twice as long as broad, outer borders all the way to the pygal marginal more and more sharply keeled anterior to the indistinct to absent horn-shield sulci, upper and nether surfaces of nearly equal area, supported by rib-ends only with the pits of the plastral digits small to indistinct and extending from the 3d to about the middle of the 7th; rib-pits small, with the 10th marginal ribless, and the 11th supporting the 9th rib anteriorly as in *Chelone* and *Lytoloma*.

Nuchal large and very broad, uniting by straight sutures with the 1st neural and 1st pleurals, between which are formed

posteriorly two small oval fenestrae as in the Trionychids; with a minute (incipient) nether articular projection but no costiform processes. Neuralia 8 with the post-neural bipar-



• FIGURE 6.—*Torochelys Bauri* (type). A supplementary figure to Plate X, showing by stippled surfaces the parts of the original carapace actually recovered. (Lettering as in figure 1.)

tite, oblong to hexagonal, prominently carinate and supporting the three large epi-neural spinose ossicles. Antero- and postero-pygals nearly as in *Lytoloma*. Pleuralia more reduced than in either *Chelone* or *Lytoloma*.

Plastron.—Of the same Chelydroid form seen in *Osteopygis* and *Lytoloma*.

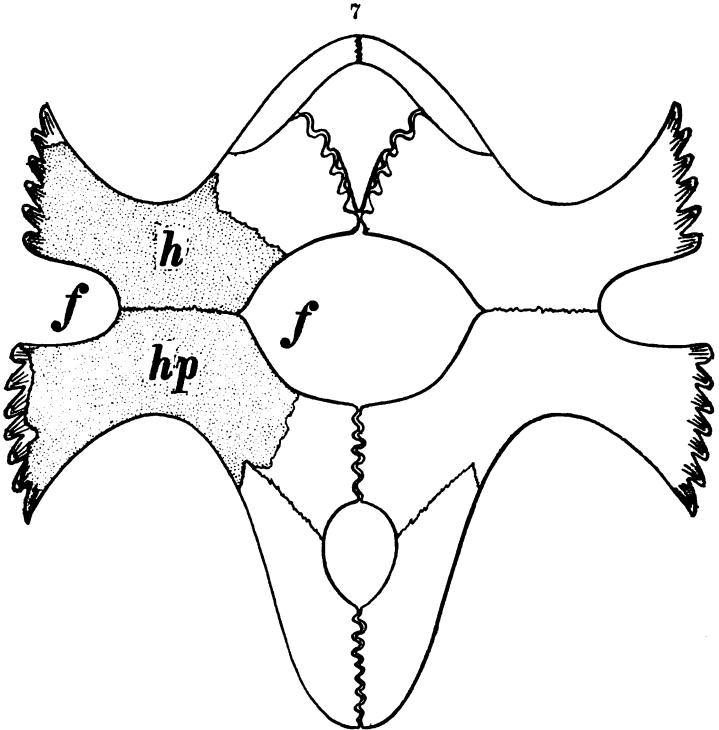


FIGURE 7.—*Toxochelys Bauri* (type). Restoration of the plastron. $\times \frac{1}{4}$.—The stippled surface shows the portions of the hyoplastron (*h*) and the hypoplastron (*hp*) actually recovered.—(The epiplastron and entoplastron is only known in *T. latiremis*, cf. figure 8, and the xiphiplastron in *T. stenoporus*.)

Specific Relationships.

The specific identity of the *Toxochelys* described in the foregoing pages with any of the known species of the genus cannot be affirmed, as appears from the following analysis.—Five species have been assigned to the Niobraran genus *Toxochelys* as first established by Cope in 1873, namely: *T. latiremis*, the generic type; *T. serrifer*, Cope, 1875; *T. brachyrhinus*, Case, 1898; and *T. procax* and *T. stenoporus*, as proposed in a recent revision of the genus by Hay (8).

With *T. latiremis* as close a comparison as desirable is not yet afforded, since but few of the elements of the carapace and plastron of this form are known. It appears, however, that the nuchal was of markedly different proportions from those

of the present *T. Bauri*, as may be noted on comparison with a nuchal figured by Case.*

Nor is there specific agreement with the nuchal of the Yale specimen I referred to, *T. latiremis*, when describing the accompanying flipper (10). This nuchal is here shown in figure 8 for the sake of more convenient reference.

8

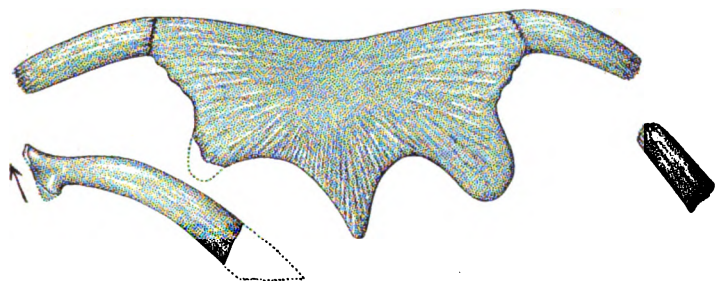


FIGURE 8.—*Toxochelys latiremis*, from the Niobrara Cretaceous, Gove County, Kansas. (Yale accession list 2419.) \times about $\frac{1}{3}$.

Nuchal with the attached first marginals of both sides and the proximal half of the right second marginal, together with the accompanying epiplastron.—This nuchal bears far back nearly in line with the front border of the large curved posterior notches a large and prominent nether process for cervical articulation.

Although true that the general form varies in turn from that just noted as figured by Case, the differences are more easily reconciled within specific limits. The simple fact is that in no previously described specimen of *Toxochelys*, and in no other semi-marine, or marine member of the Cheloniidæ, do we observe Trionychid-like foramina between the nuchal and first neural and pleurals. I may add that from recent measurements given by Hay it appears that amongst the several *Toxochelys* *T. brachyrhinus* is next related to *T. latiremis*; and there is a question in my mind if the former is a distinct species, the differences in cranial proportion from *T. latiremis* being so slight as to be of very doubtful significance in specimens so invariably crushed at more or less varying angles as are the Niobrara fossils.

With the skull fragments and crushed [9th] left marginal of *T. serrifer* as recently figured for the first time by Hay (8), I am unable to identify the present handsome specimen. As the horn-shields of *T. serrifer* formed a very deep marginal notch leading into a pronounced sulcus (as indicated by Hay), there appear to be distinct differences. It is, of course, one of the difficulties of vertebrate paleontologists that species based

* University Geol. Survey of Kansas, pl. lxxxii, figure 3.

on such meager skeletal parts accumulate in the course of time; but surely we are permitted little diffidence in applying the laws of priority and nomenclature now in vogue to a handsome and reasonably complete fossil like that discussed in the present paper. Perhaps the day is not distant when fragments will be merely noted within generic limits, and then numbered and laid aside for a certain number of years before being arbitrarily dignified as the types of new forms. Assuredly such a method would simplify the study of extinct faunæ. The extreme difficulty of reaching accurate specific identifications after most painstaking comparisons and study of descriptions primarily based on fragmentary material, has been especially brought home to the writer in his consideration of the Upper Cretaceous Turtles of New Jersey, and he has great sympathy with Professor Marsh's oft repeated contention that the types of extinct vertebrates ought to be mainly founded on fairly complete forms.

With the isolated and imperfect skull of rather large and robust form named *T. procaræ* by Hay, as with that of *T. brachyrhinus*, no comparisons are afforded by the material thus far obtained.

From *T. (serrifer) stenoporus*, finally, *T. Bauri* differs distinctly, as shown by comparison with the posterior half of the carapace figured by Case.* From that and other specimens of *T. (serrifer) stenoporus* the present fossil differs in being of a larger type with relatively heavier marginals and larger pleural plates; also in the much more pronounced sutural union of the postero- and marginalo-pygals, which is reduced to peg-like junction in *T. (serrifer) stenoporus*.

Systematic Position of the Genus Toxochelys.

Because of the carapacial organization with much reduced pleurals and marginals, as well as certain plastral characters, all suggesting primitive relationships to the Cheloniidæ, it was first suggested by the writer on his discovery of the organization of the front leg of *Toxochelys latiremis*, that the Toxochelyds do not justly constitute a separate family of turtles, as proposed by Cope and held by Hay, but are better classified as a sub-family of the Cheloniidæ, the Toxochelydinæ. Recently Hay, while accepting the principle that the limbs do furnish "a test of the correctness of this disposition of the genus," interprets the evidence differently (7). He now reaches the conclusion that Wieland misinterpreted the limbs of *T. latiremis* (10), and that these, as in the Trionychid *Amyda spinifera*, were merely long fingered and webbed,

* Kansas Univ. Geol. Sur., vol. iv, plate lxxxiii.

and not markedly modified for marine life, so that *Toxochelys* "did not navigate the open seas."

In support of his contentions Dr. Hay uses a percentual method of comparison in which the humerus is conveniently and arbitrarily considered the unit in terms of which the length of the digits is expressed. This very effective means of comparison was first used by the writer in the case of forms in other ways related, and is, within limits, unquestionably useful in a diagrammatic sense. But Dr. Hay now mistakenly employs it in a far wider application than originally contemplated, when he reaches direct conclusions as to the front limb of *Toxochelys* by comparison with the Trionychid *Amyda spinifera*, thus:—

	ARM.			FINGERS.				
	Humerus.	Radius.	Ulna.	1st.	2d.	3d.	4th.	5th.
<i>Amyda</i>	100	53	51	69	90	98	116	98
<i>Toxochelys</i>	100	58	50	51	73	100 ±	104 ±	70 ±

One might as well go on to prove that the "hawks-bill," *Eretmochelys imbricata*, is unable to "navigate the open seas".—For similarly:

	ARM.			FINGERS.				
	Humerus.	Radius.	Ulna.	1st.	2d.	3d.	4th.	5th.
<i>Amyda</i>	100	53	51	69	90	98	116	98
<i>Eretmochelys</i>	100	53	44	49	89	128	105	44

Whence the following differences:

	ARM.			FINGERS.				
	Humerus.	Radius.	Ulna.	1st.	2d.	3d.	4th.	5th.
<i>Amyda</i>	--	--	+7	+20	+1	--	+11	+54
<i>Eretmochelys</i>	--	--	--	--	--	+30	--	--

It is clear that save for that short thumb and long fourth finger of *Eretmochelys*, were this an extinct form, no conclusive evidence of the true flipper development would be afforded by such measurements as the above when considered alone. For it is a noteworthy fact that the disparity between the thumb and fourth finger of *Amyda* is +47 as against +53 in *Toxochelys*, and +56 in *Eretmochelys*. Yet as a true indication of unequal finger development, instead of disparity between only the short first and the long third and fourth fingers, as in *Eretmochelys*, there was in *Toxochelys* strong disparity between the short first and second and the long third and fourth fingers. There was also ulnar disparity.

All these fundamental numerical relations have been overlooked in Dr. Hay's criticism. He entirely ignores, too, the

fact that as a merely web-footed turtle *Toxochelys* would have been very unlike *Amyda*. For these percentual results must always be considered in connection with the humeral changes in the direction of marine forms, which are indicated in the thalassoid humerus of *Toxochelys*, as well as the enlargement of the pisiform to nearly the same size as in *Eretmochelys*. In short, it is evident that Dr. Hay overlooked important factors and that his views are untenable.

When I originally described the flipper of *Toxochelys* I was of the opinion that it represented the most primitive form yet discovered that could be called more distinctly marine than merely natatorial, long-fingered and web-footed; and now that I have had the present opportunity to briefly reconsider the subject I may say that I believe this interpretation in accord with the facts.*

Dr. Hay "readily grants that the fore limb of *Toxochelys* had entered on the early stages of those modifications which resulted in the production of flippers." But as clearly enough indicated by the facts, much more modification had been undergone, and the foot was more a swimming than a walking one. Whether the third to fifth fingers were encased in a leathery hide, or still retained some of their freedom of motion, as in distinctly webbed types, is open to some question; but nevertheless finger disparity, reduction of the 3d-5th claws, pisiform enlargement and humeral change had all been accomplished to such an advanced extent that the limb is to be regarded as a flipper, quite admirably fitting *Toxochelys latiremis* to range the great inland Niobrara Sea. And even were the anatomical facts of less certain interpretation, the *onus probandi* would rest on him who asserted the non-marine nature of those turtles which occur so widely distributed in as extensive a chalk formation of indisputably marine origin as the Niobrara Cretaceous.

It is very evident, therefore, that on the basis of limb organization *Toxochelys* is a member of the Cheloniidae, and that as proposed by the writer on the basis of the general organization, limb structure, and relationships the genus is most conveniently placed in the Chelonidan sub-family Toxochelydinae.

As a concluding word it may be added for the sake of clearness that no great diagnostic significance is attached to the presence of the epi-neural ossicles,—certainly not if they are to be regarded as vestiges of a disappearing system, likewise indicated in the genus *Lytoloma* of the Cheloninae.

Yale Museum, New Haven, Conn., Sept. 26, 1905.

* In view of the great interest of the subject I will as early as convenient refigure the flipper of *Toxochelys* with all possible care. Dr. Hay is also of the opinion that the great turtles of the Fort Pierre, and perforce the Niobrara *Protostega* were likewise littoral and web-footed rather than marine. As will be incontestably demonstrated by the writer in a forthcoming Memoir of the Carnegie Museum of Pittsburgh, *Protostega* and *Archelon* were powerfully equipped for their marine habitat.

Measurements of Carapace and Plastron of Toxochelys Bauri.

(Yale Museum accession list 2823. Elements disarticulated and more or less altered in form by crushing in matrix. Recovered portions as shown in the accompanying figure 6 by the stippled surfaces.)

Length of carapace (estimated to within 1 or 2 ^{cm}	53 ^{cm}
Breadth of carapace (greatest, as measured across the anterior end of the 6th neural)	40 +

	(a) Exact length on outer edge of carapace.	(b) Width measured at notch of the hornshield sulci.
Nuchal	12.0	--
1st marginal	6.0	2.5
2d "	5.0	2.5
3d "	5.9	2.8
4th "	6.0	--
5th "	6.5	2.8
6th "	7.0	3.3
7th "	7.5	--
8th "	8.0	4.5
9th "	7.5	4.5
10th "	7.0	4.5
11th "	6.8	4.5
Pygal	7.0	4.5

(The thickness and transverse sections of the marginals are approximately the same as in *Lytoloma angusta*. Owing to the crushing undergone by most of the marginals a closer approximation cannot readily be given.)

	Length on Median line.	Greatest width.
Nuchal	5.5	14.5
1st neural	3.8	3.8
2d "	4.4	3.7
3d "	4.4	4.0
4th "	4.6	4.4
5th "	3.4	4.5
6th "	5.0	4.0
7th "	4.0	3.8
8th "	2.5	3.5
9th "	1.5	3.5
(10th) "	2.5	3.4
Antero-pygal	4.5	5.9
(Postero-pygal)	(3.5)	(4.0)
Marginalo-pygal	4.5	6.5

1st epi-neural ossicle	3.5	1.7
2d " "	4.5	2.0
3d " "	3.9	1.5

(Thickness of 2d neural measured through carina, 1.4^{cm}.)

(The total height of the epi-neural ossicles is respectively, 15, 21, and 15^{mm}, the projection above the carina, 9, 12, and 9^{mm}.)

	(a) Length over curvature.	(b) Length of posterior sutural border.	(c) Median width.
Nuchal	---	[10]	--
1st pleural	15.0	6.5	5.7
2d " "	18.5	8.4	5.5
3d " "	19.5	8.4	5.0
4th " "	19.5	8.2	4.9
5th " "	19.0	7.7	4.8
6th " "	17.5	6.9	4.5
7th " "	14.5	5.1	3.8
8th " "	11.5	2.2	3.8

(The average thickness of the pleurals is 50^{mm}. The distance between the bases of the rib-capitulae of the 7th pleurals is 4^{cm}. The large pleuro-marginal fontanelles are approximately one-half, or more than one-half the length of the pleurals which bound them. The hornshield sulci, save for the notched marginals, are indistinct.)

The Plastron. (Cf. figure 7.)

Length on median line	39 ± ^{cm}
Greatest width	36 ±

(With added width of the inferior faces of the adjoining marginals, or 2^{cm} × 2, this measurement yields as the approximate breadth of the carapace 40^{cm}.)

Width (on antero-posterior line) of the marginalohyo-hypoplastral fontanelle	5.0
Length of hyo-hypoplastral suture	6.3
Least width of the hyo-hypoplastral bridge	11.0

References.

1. Boulenger, G. A. : Catalogue of Chelonians, British Museum of Natural History, 1889.
2. Case, E. C. : *Toxochelys*. University Geological Survey of Kansas, Paleontology, Part IV. Topeka, 1898.
3. Cope, E. D. : Vertebrata of the Cretaceous Formations of the West, vol. ii, Rep. U. S. Geological Survey of the Territories. Washington, 1875.
4. Fraas, E. : *Proganochelys Quenstedtii* Baur (*Psammochelys* Keuperina Qu.). Ein neuer Fund der Keuperschildkröte aus dem Stubensandstein. Jahreshefte des Ver. für Naturk. in Württemberg. Stuttgart, 1899.
5. Gray, J. E. : Supplement to the Catalogue of Shield Reptiles in the British Museum. London, 1870.
6. Hay, O. P. : On the skeleton of *Toxochelys latiremis*. Publications of the Field Columbian Museum. Zool. I. Chicago, 1895.
7. ——— On the group of Fossil Turtles, known as the Amphichelydia; with Remarks on the Origin and Relationships of the Suborders, Superfamilies, and the Families of the Testudines. Bull. American Museum of Natural History, vol. xxi, Article IX. New York, June 30, 1905.
8. ——— A Revision of the species of the Family of Fossil Turtles called Toxochelyidæ, with Descriptions of two New Species of *Toxochelys* and a New Species of *Porthochelys*. Ibid., Article X.
9. Wieland, G. R. : *Archelon ischyros*: A new gigantic cryptodiran Testudinate from the Fort Pierre Cretaceous of South Dakota. Ibid., vol. ii, Dec., 1896.
10. ——— Notes on the Cretaceous Turtles *Toxochelys* and *Archelon*, with a classification of the Marine Testudinata. Ibid., vol. xiv, Aug., 1902.
11. ——— Structure of the Upper Cretaceous Turtles of New Jersey: *Adocus*, *Osteopygis*, and *Propleura*. Ibid., February, 1904.
12. ——— Structure of the Upper Cretaceous Turtles of New Jersey: *Lytoloma*. Ibid., Sept., 1904.

ART. XXXVII.—*Contributions to the Geology of New Hampshire. I. Geology of the Belknap Mountains*; by L. V. PIRSSON and H. S. WASHINGTON. (With Plate XI.)

Introductory Note.—Our object in this paper and in one to follow it is to present the results of a study made in the field and in the laboratory of the occurrence and characters of a group of igneous rocks from a locality about which little is known. Our field work was done in two visits to the area and covers a period of between two and three weeks, during which it was traversed and roughly outlined and the highest peaks and ridges ascended. This was sufficient to give a good general idea of its geology and of the various rock types. In the lack of a suitable base map on a sufficient scale, upon which to make record, more detailed and careful work was not warranted and would have enabled us to add little of interest to the general results presented in this paper. The map used and upon which our results are given is taken from that accompanying the Hitchcock Survey, referred to later, and which we have modified to some extent. The topography is more or less generalized and in places somewhat inaccurate, but it is the only one showing topography of which we have any knowledge and it has served as the basis of several topographic maps since published for the use of tourists which we have also consulted.

LOCATION AND GEOGRAPHY.

The Belknap Mountains form an elevated tract south and west of Lake Winnepesaukee in New Hampshire and lying in the townships of Gilford, Alton and Gilmanton. Although they are sometimes referred to as the "Belknap Range" they do not form a mountain range of the anticlinal type, being the irregular, eroded upper portion of a great intrusion of igneous rock of a generally granitic character. In its greatest length, which is northwest and southeast, the mountain tract extends about eleven miles and its width at the broadest point east and west is about six miles. In shape the mass is triangular, the long side facing the west composed of the main ridge which carries the highest summits, while an eastward extension produces the triangular shape. At the eastern end of the triangle there is an extension running southward. On the north and east sides the slopes descend into Lake Winnepesaukee; on the west and south into a much lower, irregularly hilly country. The drainage on the west is carried off by the Gunstock River, which in its course of about six miles runs due north at the foot of the mountain slopes in a valley cut along the contact

zone of the igneous rock mass. On the south the drainage is less clearly defined and is carried off through a series of small lakes which empty to the southward. On the other sides small brooks run into the lake. The mountains are quite generally covered with trees and brushwood on the steeper slopes; below these are generally open pasture fields, and the highest crests and summits are more or less bare rock exposures with small meadows between them. At the foot of the eastern and northern slopes, along the shore of Lake Winnepesaukee, runs the Lake Shore Railroad, a branch of the Boston and Maine Railway system, which ends at Lakeport-Laconia. These towns with Alton Bay at the south end of the lake and the village of Gilford are the most important places in the vicinity of the mountains, although the shore of the lake at their foot is thickly dotted with summer cottages and places of resort. Around them elsewhere is an open farming country and the high valley between the northern extension and the eastward one of Mount Straightback is also a cultivated area reached by a road over the mountains from Gilford to West Alton.

Historical.—The only reference in the literature to the geology of the Belknap Mountains which we have been able to find is the short description by Hitchcock.* He states that the mountains are composed of eruptive syenite similar to that of Red Hill in Moultonborough. He describes briefly a few localities, and mentions that in places it is in contact with porphyritic gneiss and mica schist. He thinks that the syenite has come up through a synclinal fault. Near the contact with the porphyritic gneiss it is brecciated and full of dark hornblendic spots. He alludes to a "trap" dike ten feet wide cutting the syenite in one place, and says that reddish feldspathic veins are common. This is an evident reference to one of the lamprophyric dikes and the felsitic ones. He also refers to a breccia which is found in one locality, the coarser syenites occurring as nodules in a rock resembling trap. The mass of diorite (camptonose) rock above the Gilford station on the lower west slope of Locke's Hill is not mentioned and was probably not seen by him. In Hawes'† report the rocks of this area are not mentioned, although he describes the syenite of Red Hill.

GEOLOGY OF THE BELKNAP MOUNTAINS.

The Belknap Mountains are formed of a mass of granitic igneous rock, the result of the upthrust of a great body of molten magma into the rock masses surrounding it, the latter being broken and displaced to permit of its entry. In sequence to this major event there were later upthrusts of other magmas

* *Geology of New Hampshire*, vol. ii, p. 607, 1877.

† *Lithology of New Hampshire*, loc. cit., vol. iii.

of different composition in small amounts which now appear as accompanying intrusive masses and dikes. Since then the superincumbent rocks have been removed by long-continued erosion, which has also bitten deeply into the igneous mass as well, but this has resisted better than those which surround it, and in consequence the igneous stock now projects as a rough mountain tract. Lastly, much material was removed at the time of the glacial invasion and the rock surfaces left scored and polished.

The enclosing rocks.—These are mostly gneisses and mica schists, rocks of metamorphic character. Although they do not especially concern us in this paper, a word or two may be added regarding them. On the eastern side the contact is with a heavy solid gneiss, composed of quartz, alkali feldspars and biotite, and often carrying red garnets. In its texture it is rather irregular, not presenting that evenness of aspect frequently shown by gneissoid granites, and it is possible that detailed study in the future may show that it is of sedimentary origin. It has a wide extension in this general region and has been called the Winnepesaukee gneiss by the Hitchcock Survey.

In Mount Major and Pine Mountain are two small masses of a porphyritic granite as shown on the map of the Hitchcock survey. In their report it is spoken of as the porphyritic gneiss. It covers a large area to the north of this region, where we have seen and studied it to some extent. By its general characters, contact modifications, etc., it is clearly an igneous rock—a granite which carries large, often huge, phenocrysts of orthoclase. It occurs in other parts of New England and is a type worthy of especial study. It sometimes has a pronounced gneissoid structure which evidently is often a fluxion texture, at other times it is due to dynamic shearing and in some places it is quite devoid of any gneissic character.

On the west and south the Belknap massif is in contact with micaceous gneisses, micaceous slates colored dark with organic matter and iron ore and with mica schist rocks evidently of sedimentary origin. The boundaries and names of these formations are those given on the Hitchcock map. The lack of printed symbols on this map connecting the legend with the outlined areas and the great similarity of colors makes it exceedingly difficult, in many cases impossible, to determine what some of these areas are meant to be, nor does the text afford much help in this direction. The formations are mentioned in many places, but there is no definite description of them given in a systematic manner by which their characters may be recognized. From what is stated,* however, we conclude that the rocks on the west belong to the Montalban series

* Op. cit., vol. ii, p. 600.

of Hitchcock, and they are so designated on the map. Where we have seen them they are mostly gray micaceous gneisses and mica schists.

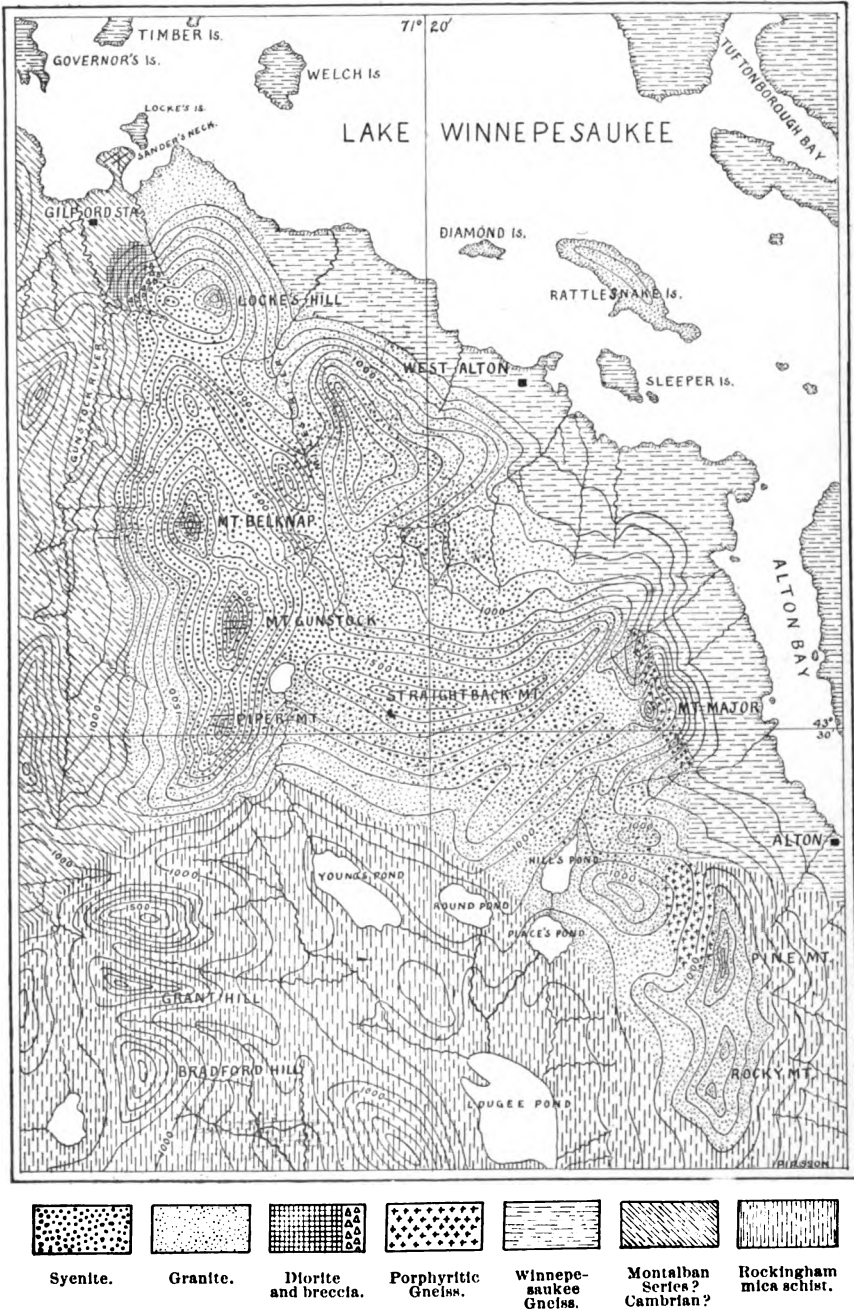
Geology of the main mass.—The greater part of the mountain group is made up of a coarse-grained hornblende syenite, a *hornblende-grano-pulaskose* in the new classification, whose characters will be given in a succeeding petrographical paper. It is this rock which composes the mass of Mt. Gunstock, of Mt. Belknap the peak next north of it and of the northern extension in Locke's Hill. It occurs also in the ledges exposed on the higher part of the road from Gilford to West Alton, where it crosses over the mountain. It also forms the higher parts of Piper Mountain south of Gunstock Peak, and it runs over towards Mt. Straightback. In Piper Mountain it assumes a somewhat porphyritic character. It is seen on the sides and crests of the main elevations in massive outcrops and exposures often several hundred feet across and is thus thoroughly laid bare. These surfaces show everywhere the planing and smoothing of glaciation. In none of them did we find the rock perfectly firm and unchanged. Everywhere its color ranges from a reddish to brownish, it tends to crumble under the hammer and in places it is loose and crumbling into coarse gravel. The chemical analysis shows however that this is not due to any chemical alteration of the constituent minerals, but to mechanical disintegration from the action of frost and weathering, which have tended to loosen the texture of the rock. Blasting would probably reveal excellent material at a few feet below the surface. We did not find any quarry openings in this rock-material; it is in general too high above the zone of cultivation to have made such work necessary. In only one place did we find this type at the contact zone against the older rocks, on the southwest slope of Locke's Hill in a little ravine where it is in contact with mica schist. It is here rather coarse, altered and not of typical composition.

Contact facies of fine-grained granite.—With the exception just mentioned, in all localities examined by us, we have found that at the contact with the enclosing rocks, not the syenite but a fine-grained granite (*grano-liparose*) is present. The lower slopes where the actual contact lies are in general so covered with glacial drift and soil, often with a more or less dense growth of vegetation, that it is masked and rarely seen, but immediately above where it should be this granite appears and beyond and above it the syenite. This we found to be the case in a number of places on different sides of the mass, so for example at the west foot of Mt. Gunstock, the west and south slopes of Piper Mountain, the northeast foot of Locke's Hill, at West Alton and on the southern prolongation of the

mass northeast of Hill's Pond. Hitchcock's description also gives clear indications of the same thing in other localities not visited by us. One of the best localities for the study of the contact that was seen by us is at the foot of the west slopes running down from the north end of Piper Mountain in the pasture fields south of Morrill's farm, where the path, by which Mt. Gunstock is generally ascended, begins. The mica schists and other rocks, which we infer make the formation shown by Hitchcock on his map as the Montalban, are full of pegmatite and fine granite stringers and dikelets and appear to be enriched in feldspar. As the contact is approached they change to a fine dark-gray gneiss which is cut by fine granite dikes. Higher up appears the syenite itself. The attitude and characters of the gneisses are such that they indicate quite clearly that they lie, thinning out toward the mountain, upon a rising slope of the igneous rock below and that the contact plane is therefore here not vertical but dipping away from the mountain. The syenite from the slopes above is that of the main type but finer-grained. At the south end of Piper Mountain the bordering granite has a faint but distinct gneissoid appearance. It is also to be noted that these bordering masses of granite are generally filled with spots and streaks of variable size of darker inclusions, which are no doubt fragments of the country rock thoroughly altered by immersion in the magma.

It appears to us that the best explanation for these fringing granite masses is to consider them a differentiated border facies, an endomorphic contact modification of the main type. They may not exist everywhere, but they have been so generally found on different sides, as seen by ourselves and indicated by Hitchcock, that the phenomenon seems difficult of explanation on any other basis. It is true that we have not been able on continuous exposures to trace the gradual merging of the granite into the syenite, because this should be done on the lower slopes, and for reasons given above these do not afford proper exposures for this purpose. We cannot affirm then positively that these are not a series of later eruptions which have broken out around the border of the previously intruded syenite, but in view of their disposition such an explanation seems unnatural, and especially so since they do not exhibit certain phenomena shown by an undoubted later intrusion of granitic magma on the western slope of Locke's Hill, which will be presently described. From the facts at our command, therefore, we are inclined to think the first explanation the more reasonable one and to regard the granite as a differentiated border mantle of the syenite. We also do not regard the granite border as having been produced by the melting up

Geologic and Topographic Map of the Belknap Mountains, N. H.



Scale 1 inch = 2 miles. Contour interval = 100 feet.

and absorption of the country rock with which the mass of syenite magma came in contact for two sufficient and convincing reasons. First, because as already shown, the surrounding rocks differ widely in character and in chemical composition in different places, while the granite border maintains everywhere essentially the same characters, and second, because in many places inclusions of the country rock are to be seen in it which, without regard to size, preserve all the sharpness and angularity of their original fragmentary form, thus showing that, although they have been much metamorphosed, melting of them did not occur. On the highest peaks and ridges and in the deepest erosive cuts into the mass it has been worn away and the main type of syenite appears. Its thickness was quite variable, and in a few places it did not appear at all. The line between the syenite and granite as shown on the geological map is therefore to be taken as a generalized expression of the existence of the two types and not as a definite geological boundary line, since for reasons just given this could not be definitely determined.

Gilford diorite area.—On our first visit to the region we found quite abundantly distributed in the form of bowlders in the fields and stone walls of the fences along the higher part of the land from Gilford over to West Alton, a most peculiar dark rock composed of large dark-brown hornblendes poikilitically enclosing ophitic feldspars. In field usage it is here called a diorite for purposes of geologic description; petrographically it is, as will be shown later, a grano-hornblende-camptonose, or in the older systems an essexite. On our second visit an especial search was made to locate if possible the occurrence of this type, and it was found to constitute a considerable mass on the lower west slope of Locke's Hill and not far from the Gilford station on the railway. Its area is small, probably not over half a mile in length north and south along the slope and less than that in breadth. On the north it rises in heavy ledges above a little spring drainage and on the west its lower slopes are covered with soil and debris, but above this it forms a rather well-defined bench on the lower mountain side and in rather prominent outcrops it is seen everywhere over the pasture fields which lie upon it. On the south it descends into a little ravine, a locality mentioned above in connection with the syenite, and is here in contact with the mica schists and gneisses. Its upper edge is in contact with the syenite, but the actual contact was everywhere covered so far as we could discover. We have traced it, however, to within a few yards distance, and it is then observed that the rock diminishes very strikingly in the size of its grain, especially so with regard to the large poikilitic hornblendes, and for this reason and others to be mentioned later we believe

it to be a later intrusion than the syenite and that it has broken up alongside of it. The upper contact with the syenite is, however, largely replaced by a remarkable breccia zone to be presently described. This rock varies considerably in characters from place to place, as will be described in a succeeding petrographic paper.

Breccia zone.—As just mentioned, the contact between the diorite and syenite above is occupied by a brecciated rock mass. The cement is a quartz-alkali feldspar rock much like the granite facies previously described; it has a sugar granular texture, and is of the character of rocks designated as aplites. In this are thickly scattered blocks of all sizes, which may attain an extreme dimension of four feet in length but which average perhaps a foot or two in diameter and descend from this size to minute fragments of a fraction of an inch. In some places they are so thickly crowded that their mass is much greater than that of the cement. In shape they are usually extremely angular and the sharpness of the angles has been perfectly preserved. In other cases they appear somewhat rounded as if partially melted, and are surrounded by darker aureoles richer in ferromagnesian minerals. It is remarkable, on the other hand, how some of the smallest fragments retain in some cases all their distinctness of outline. There are several different types of rocks among these included fragments. One common one is a dense black basaltic-looking type too compact for the component minerals to be seen, in which lie phenocrysts of mica and other minerals—a rock of well defined lamprophyric character. Other fragments are of the diorite mentioned above, while others are obviously pieces of gneisses and schists.

The determination of the relative age of this breccia and of the syenite and diorite is not easy. It would be simple to imagine that the latter is the older rock, that the syenite with its granite border broke up alongside of it enclosing masses of fennic rock. If this view is adopted, then the basaltic, lamprophyric and granitic and felsitic dikes which cut the syenite must of course be separate and later intrusions and there would be four periods of eruption, in two of which, those of the diorite and the lamprophyric dikes, similar magmas were produced. The oldest rock, the diorite, is then also the most differentiated one, a fact contrary to general experience. Considering these points, we are inclined to believe the syenite the first and oldest, to place the eruption of the diorite next, which would also explain the distinct endomorphic contact modification it exhibits toward the syenite and make it contemporaneous with the lamprophyric dikes. Then came an eruption of granitic magmas, which also forms dikes in the syenite, one of

which broke up at the border of the diorite, involving masses of it in its various modifications and thus produced the breccia. If this view is adopted, there are but three periods of eruption and they follow the normal course commonly seen in such cases.

Dikes.—It has been observed by us that wherever the main types of igneous rocks are exposed over considerable areas in this mountain tract they are commonly cut by dikes, and the same is true of the border zone of the enclosing schists and gneisses. Except, however, in the highest parts of the mountains, such exposures are not very common nor are they of great size. It seems probable, therefore, that only a very small part of the dikes actually present in the region has been seen by us, the greater part being covered up by the heavy mantle of debris and glacial drift.

As is so often the case when the dikes are found to be a throng of satellites attendant upon a large body of igneous rock, they may be readily referred to two strongly contrasted groups. In one of these the rocks are light colored, strongly persalitic and therefore almost devoid of ferromagnesian minerals; in the second the rocks are dark colored, saffemic, heavy and composed in very large, if not for the greater part, of ferromagnesian minerals. They are persalanes and saffemanes in the new classification or aplites and camptonites in the older ones.

The *persalane* dikes are found cutting the main syenite in all directions, of a generally pink color and varying in size from dikelets but a few inches in breadth to masses twenty feet wide. The bare exposed slopes and ledges of the upper part of Mt. Belknap were found cut by them in great abundance and it was here noticed that they often ended abruptly and appeared as if somewhat elongated roughly lenticular masses. They were often branched, were connected with others, anastomosed or formed reticulated systems, large and small together. Their small angular chippy jointing, light color on the weathered surface and flinty felsitic aspect clearly distinguished them from the massive granular rock they cut. These same characters were found repeated on the exposed surfaces of Mt. Gunstock and Mt. Piper, and in one place, about half way up Mt. Gunstock from Morrill's house, on the west slope above the spring, the ledges in a pasture field on an open shoulder of the mountain were found cut by a dike of this nature 15-20 feet in width and with north and south trend. It was also found that where the contact zone was exposed at the foot of the mountain slopes, as along the west side in the localities described above, that both the igneous rock and the enclosing schists and gneisses were cut by dikes and stringers

of persalitic rock. While in the crest of the ridges and in the peaks these dikes vary in texture from dense felsitic to sugar granular granites, in the contact zone we observed only the latter, and they sometimes pass into varieties with pegmatoid texture.

With only a few exceptions all of these occurrences are on too small a scale to be shown on the map. The *salfemane* dikes were not nearly so numerous, but on account of the contrast made by their dark color appear more distinctly defined. They were also observed cutting the exposed rock surfaces on the tops of the mountains; there are several below the summit of Mt. Belknap on the southwest side and one six feet wide with porphyritic feldspars cuts the very highest point of the peak with east and west trend. Three or four of about the same size were found on the top of Mt. Gunstock and they were likewise observed on the crest of Mt. Piper. The lower slopes of the mountains are probably cut by them also, but the masses of debris and vegetation which cover them hide the exposures in which they might be seen.

They occur also in the surrounding rock masses in which the intrusion took place. Here again the exposures are difficult to find, but one place, Sander's Neck, a small promontory on the shore of the lake north of the mountains, presents considerable areas of the glaciated gneisses, and these we found traversed by several intersecting dikes of these *salfemic* rocks. As usual they were but a few feet in width. They occur in the mica schists which are exposed at the foot of the lower west slopes of Mt. Gunstock and Mt. Piper, and from what we have observed around the similar intrusive mass of Red Hill north of the lake, it seems probable that a more detailed study of the surrounding region would show a considerable number of them extending to relatively long distances from the central parent mass. Some of those mentioned above are shown on the accompanying map.

New Haven, Conn., and Locust, N. J., May, 1905.

ART. XXXVIII.—*The Fauna of the Chazy Limestone*;* by
PERCY E. RAYMOND.

INTRODUCTION.

IN several papers on the Chazy limestone, Brainerd and Seely have given sections showing the lithological characters and thickness of the rocks at various localities from Chazy, New York, south to Orwell, Vermont.† These authors have divided the formation into three parts, A, B, and C, of which A is the base and C the top. These divisions are founded partly on lithologic and partly on paleontologic grounds. Only a few species of fossils, however, were listed; hence it has been the object of the present writer to ascertain which are the common species in the Chazy, and to learn their stratigraphic and geographic distribution. For this purpose, detailed sections have been made at Crown Point, Valcour Island, and Chazy, and extensive collections have been obtained at other places in the Champlain and Ottawa valleys. The sections will be fully described in the *Annals of the Carnegie Museum*. In this place, however, only a synopsis of each is given.

DISTRIBUTION.

The Chazy formation was named by Ebenezer Emmons‡ from the outcrops studied by him at Chazy village, New York, this locality, therefore, becoming the typical one for the formation.

In stratigraphic position, the Chazy overlies the Beekmantown (Calcareous) and underlies the Lowville (Birdseye) member of the Mohawkian. It may be traced from Orwell, Vermont (along the Champlain Valley), to Joliette, north of Montreal, Canada. In the Ottawa Valley, it extends from Hawksbury west to Allumette Island, 80 miles northwest of Ottawa. The formation is seen again at the Mingan Islands in the St. Lawrence, where it covers a small area.

In the Lake Champlain region, these strata are mostly limestone, and the thickness ranges from 60 feet at Orwell to 890

* Abstract of part of a thesis presented to the Faculty of the Yale University Graduate School for the degree of Doctor of Philosophy. The detailed paper, with full discussion and illustration of species, will be published in early numbers of the *Annals of the Carnegie Museum*. For description of the trilobites here mentioned, see *Annals of the Carnegie Museum*, vol. iii, p. 328, and this *Journal*, vol. xix, p. 377. Other new forms noted in the text are described at the end of the present paper.

† *Amer. Geol.*, vol. ii, p. 323, 1888; *Bull. Geol. Soc. Amer.*, vol. ii, p. 300, 1891; *Bull. Amer. Mus. Nat. Hist.*, vol. viii, p. 305, 1896.

‡ *Geology of New York*, Pt. 2, Report of the Second District, 1842, p. 107.

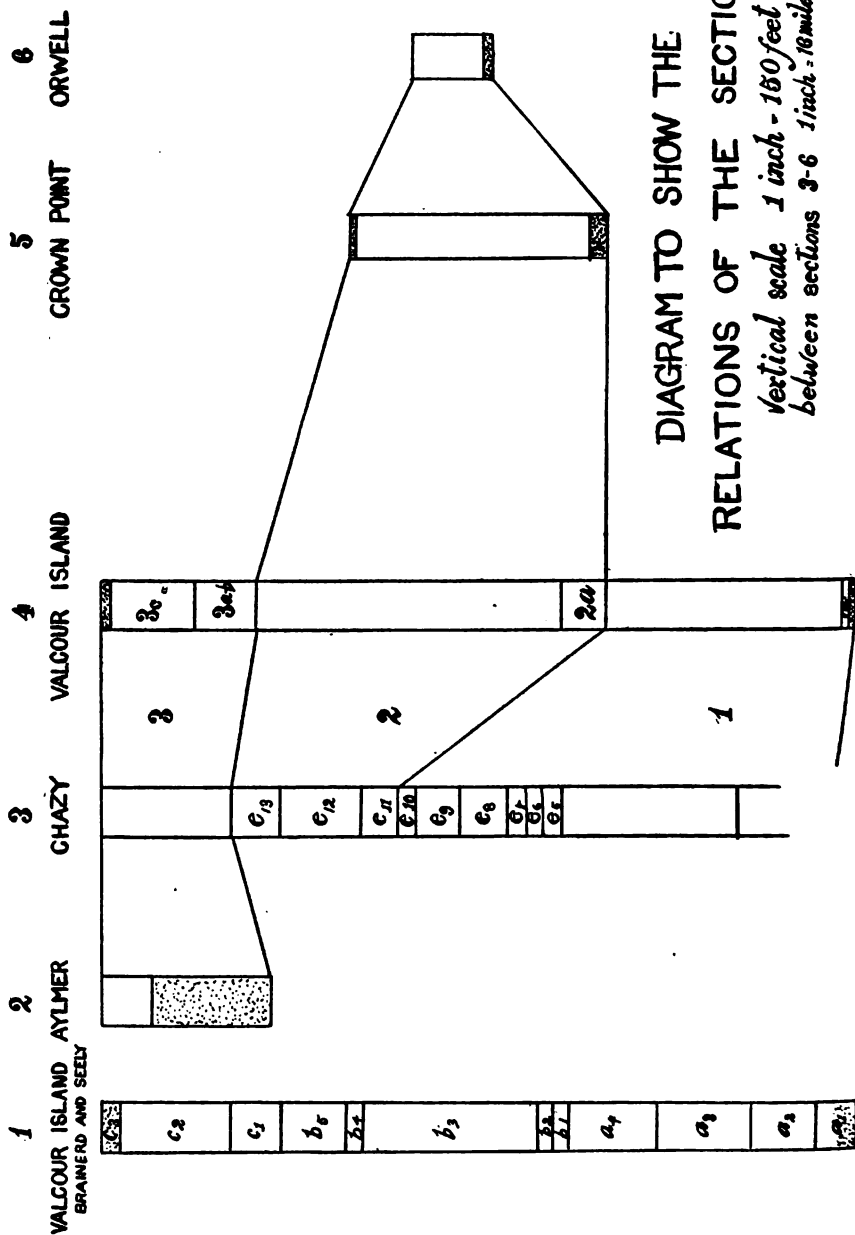


DIAGRAM TO SHOW THE
RELATIONS OF THE SECTIONS
*Vertical scale 1 inch - 150 feet
between sections 3-6 1 inch - 10 miles*

feet at Valcour Island. Further north the thickness is not definitely known. In the Ottawa Valley, the formation is usually from 100 to 200 feet thick and is about half limestone and half sandstone, the former usually overlying the latter. At the Mingan Islands, the thickness was estimated by Sir William Logan at about 300 feet, and the strata include both shales and limestone.

LAKE CHAMPLAIN REGION.

As the typical Chazy is exposed in the Lake Champlain region, that area will be first taken up. In general, the Chazy rocks are seen as a narrow belt running almost north and south from Orwell, Vermont, to Joliette, Canada. The area is seldom more than 10 miles wide, and is not a continuous exposure, but occurs in small patches, in most cases evidently fault blocks, and the strata are usually inclined at a considerable angle. The principal outcrops are along the west side of Lake Champlain and on the islands in the northern part of the lake. South of Willsboro Point, there are scattered patches on both sides of the lake nearly to Fort Ticonderoga.

Faunal Divisions.

In the Lake Champlain region, three major faunal divisions of the Chazy may be distinguished. Within these, there are again various zones which are more or less local in geographical extent.

Division 1. The Hebertella exfoliata Division.—The strata of this basal division are chiefly light-colored, impure, rather coarse-grained limestones and frequently have shaly partings. The thickness varies from nothing at the south end of Lake Champlain to 300 feet on Valcour Island, 365+ at Chazy, and 225 feet on Isle La Motte.

The characteristic fossils are: *Hebertella exfoliata* sp. nov., *Orthis acutiplicata* sp. nov., *Strophomena prisca* sp. nov., *Scenella pretensa* sp. nov., *S. montrealensis*, *Palæacmæa irregularis* sp. nov., *Raphistoma immatura*, and *Scalites angulatus*. Other species occurring abundantly in this zone are: *Blastoidocrinus carchariædens*, *Bolboporites americanus*, *Zygospira acutirostris*, *Raphistoma stamineum*, *Lophospira subabbreviata*, *Bucania sulcatina*, and *Pseudosphærexochus chazyensis*. Those which occur only rarely in this division, but which thus far have not been found in higher divisions, are: *Lingula belli*, *Cyrtodonta solitaria* sp. nov., *Cyclonema? normaliana* sp. nov., *Eunema leptonotum* sp. nov., and *Heliomera sol.*

Of the 141 species in the Chazy whose range is known, 64 make their first appearance in this horizon and 23 are found in

all three divisions. This member is further marked by the appearance of the earliest of American Bryozoa, and these, unlike most Ordovician species, range throughout the entire formation above the sandstone.

Division 1 is characterized by the predominance of individuals and species of Brachiopoda. Fourteen of the 25 species of this group occurring in the Chazy of the Champlain Valley are found in this lowest member, while only 2 of the 16 pelecypods are represented. Exactly half the species of trilobites are also found here, but specimens are not common. Gastropods are more numerous, as half the species are represented and individuals of some forms are abundant. They do not occur in the lower strata, but are confined almost entirely to the upper part.

There are three zones in this division which are worthy of notice:—

Zone 1_a, or the *Orthis acutiplicata* zone, is near the base of the division and is found at Valcour Island and Isle La Motte. The characteristic fossils are: *Orthis acutiplicata*, *Rafinesquina incrassata*, *Isotelus harrisi*, and *Thaleops ovata*, all long rangers except the first.

Zone 1_b. The *Scalites angulatus* zone. The faunule of this zone is found at Plattsburg and Chazy. It is located near the middle of Division 1. The characteristic fossils are: *Scalites angulatus*, *Raphistoma immaturum*, *R. stamineum*, *Bucania sulcatina*, *Camarella longirostris*, *Ilænus globosus*, and *Thaleops ovata*. Only the first two are restricted to this horizon.

Zone 1_c, the *Lophospira subabbreviata* zone, has been found only at Chazy, but is very strongly marked. It occurs about 75 feet below the top of Division 1. The characteristic fossils are: *Lophospira subabbreviata* and *Raphistoma stamineum*, both of which are very abundant. Of less importance are the rare *Schizambon? duplicimuriatus*, *Heliomera sol*, and *Clionychia marginalis* sp. nov.

Division 2. The *Maclurites magna* Division.—The strata of this middle division are usually heavy bedded, dark blue and grey, fairly pure limestones, with an occasional layer of grey sparkling dolomite or of light coarse-grained limestone. The layers near the middle usually weather into nodular masses, and the fossils are frequently poorly preserved and difficult to extract. The thickness varies from 200 feet at Chazy to 400 at Valcour Island, and decreases toward the south. The characteristic fossils are: *Maclurites magna*, *Rafinesquina champlainensis*, *Plæsiomys platys*, *P. strophomenoides* sp. nov., *Strophochetus*, *Eospongia varians*, *Eotomaria obsoletum* sp. nov., *Eccyliopterus fredericus*, *Bathyuirellus minor*, *Glaphurus primus*, and *Lepeditia limatula* sp. nov.

Thus far, the following fossils have been found only in this division, and most of them in but one locality: *Camarotoechia pristina* sp. nov., *Ctenodonta dubiaformis* sp. nov., *Clidophorus obscurus* sp. nov., *Cyrtodonta expansa* sp. nov., *Endodasma undulatum* sp. nov., *Scenella robusta* sp. nov., *Raphistoma undulatum* sp. nov., *Helicotoma vagrans* sp. nov., *Bucania bidorsata*?, *Trochonema dispar* sp. nov., *Subulites prolongata* sp. nov., *Holopea scrutator* sp. nov., *Eoharpes ottaväensis*, *Asaphus marginalis*, *Isotelus angusticauda*, *Isotelus*? *bearsi*, *Ilænus punctatus*, *Cybele valcourensis*, *Ceraurus pompilius*, *C. hudsoni*, and *Pseudosphærezochus approximus*.

This middle division is marked by an abundance of pelecypods, gastropods, and trilobites, and in this respect is sharply contrasted with the lower division. Of the 16 pelecypods, 13 are represented here. Of 35 trilobites, 27 are present.

Species of *Stromatocerium* and *Strephochetus* are common in these rocks, but are also abundant in the lower zone of the next division.

Zone 2_a. The *Malocystites murchisoni* zone. Thus far, only one subfaunule has been detected in Division 2, and that is at the very base. It is best developed at Valcour, but occurs also on Valcour Island. The zone is characterized by the great abundance of cystid fragments. The characteristic fossils are: *Glaphurus primus*, *Eoharpes antiquatus*, *Lonchodomas halli*, *Cybele valcourensis*, *Malocystites murchisoni*, *M. emmonsii*, *Glyptocystites forbesi*, *Palæocystites tenuiradiatus*, *Raphistoma stamineum*, *Maclurites magna*, *Plæsiomys strophomenoides*, and *Camarella varians*.

Division 3. The *Camarotoechia plena* Division.—The strata of this division are rather thin bedded, light grey, coarse-grained limestones, abounding in fossils. Near the base there are always buff-colored, pure, fine-grained dolomites and heavy bedded, coarse-grained blue limestones. The only fossil which is found throughout this division is *Camarotoechia plena*. Other characteristic fossils are: *Camarotoechia major* sp. nov., *Orthis ignicula* sp. nov., *Modiolopsis fabaformis* sp. nov., and *Glaphurus pustulatus*.

There is here a decided falling off in the number of gastropods and pelecypods, only 6 of the former and 5 of the latter being represented. There are about as many trilobites (16) in this division as in Division 1, and 8 of these are found in all three sections. The number of species of brachiopods is about the same in each of the three divisions, but they dominate the fauna in the first and third. In the former, one of the Protre mata (*Hebertella*) is most abundant, while in the third division one of the Telotre mata (*Camarotoechia*) predominates.

There are three well-marked zones in this division, as follows:

Zone 3_a, the *Glaphurus pustulatus* zone, is found at the base of Division 3, at Valcour Island, Chazy, Cooperville, and Isle La Motte. The characteristic fossils are: *Glaphurus pustulatus*, *Illænus globosus*, *I. erastusi*, *Isotelus harrisi*, *Remopleurides canadensis*, *Pliomerops canadensis*, *Amphili-chas minganensis*, *Pseudosphærexochus vulcanus*, *Camarotechia plena*, *Conocardium beecheri* sp. nov., *Bucania sulcatina*, and several cephalopods.

Zone 3_b, the *Camarotechia major* zone, stands between 3_a and 3_c and its faunule is a transition between the two. *Camarotechia* becomes more abundant and better developed, and fossils, while numerous, become fewer in species. The best development is at Valcour Island. The characteristic fossils are: *Camarotechia plena*, *C. major*, *Hebertella costalis*, *Malocystites emmonsii*, *Malocystites* sp., *Palæocystites* sp., *Illænus globosus*, *Pliomerops canadensis*, *Bucania sulcatina*, *Raphistoma stamineum*, and *Isotelus obtusum*.

Zone 3_c. The *Modiolopsis fabaformis* zone. In this zone, *Camarotechia plena* is abundant, almost to the exclusion of other species. The faunule extends to the top of the formation at Chazy, Grand Isle, and Valcour Island. The characteristic fossils are: *Camarotechia plena* and *Modiolopsis fabaformis*.

Section at Chazy, New York.

The section at Chazy has a thickness of 732 feet, but the base of the formation is not shown.

Division 1.—The rocks carrying the fauna of Division 1 are well exposed in the ridges south of the village, near Tracy Brook. The thickness is 365 feet, and judging from the fauna at the base, at least 150 feet of strata are missing. *Hebertella exfoliata* is very abundant, especially below the horizon of *Scalites angulatus*. The latter zone is 217 feet above the base of the exposed section, and is zone 1_b of the generalized section. The most common fossils are: *Scalites angulatus*, *Bucania sulcatina*, *Raphistoma immaturum*, *R. stamineum*, and *Thuleops ovata*. Higher up in the section, 275 feet above the base, is the zone of *Lophospira subabbreviata*, about 35 feet in thickness. This is zone 1_c of the generalized section. The gastropods are very abundant in the three localities at Chazy where this zone is exposed.

Division 2.—The strata of this division are about 195 feet in thickness, and are dark blue, impure nodular limestones, usually full of fossils which are frequently silicified. *Stroma-*

tocerium, *Eospongia varians*, *Rafinesquina champlainensis*, *Plæsiomys platys*, *Maclurites magna*, *Pliomerops canadensis*, and several cephalopods are common.

Division 3.—The *Camarotoechia plena* division is not very well developed along the line of the section at Chazy. The thickness is 156 feet, but a large part of the strata is covered with soil. At the base are about 25 feet of grey dolomite with almost no fossils. The remainder of the rock, as far as exposed, is an impure shaly limestone, abounding in *Camarotoechia plena*. Zones 3_a, 3_b, and 3_c can not be distinguished just at Chazy village, probably because the strata are so poorly exposed. About 3 miles southeast of this point, however, in a field near the lake shore, five outcrops of zone 3_a occur, and here *Glaphurus pustulatus*, *Amphilichas minganensis*, *Illænus globosus*, and the cephalopods are common.

Section at Valcour Island.

On Valcour Island, the whole of the Chazy is exposed, with a thickness of 890 feet. In one section along the south end, almost the entire thickness is shown, while nearly all the missing parts may be seen in other sections on the east and north sides of the island.

Division 1.—The strata of this division are well exposed on the south end. The thickness is 314 feet. At the base is a zone of sandstone and shale in which *Lingula brainerdi* is the common fossil. Other fossils are rare, *Isotelus harrisi* and a species of *Eccyliopterus* being the only ones thus far found. Above this zone is that of *Orthis acutiplicata*, 10 feet in thickness.

The *Scalites angulatus* zone is not exposed on Valcour Island, the rocks usually containing it being absent at the pebble beach on the south end of the island. The *Lophospira subabbreviata* zone is not well developed, but may be indicated by a fauna found on the middle of the west side.

Division 2.—The strata of this division are 406 feet in thickness and are usually compact, dark blue and grey limestones. The fossils are frequently coarsely silicified, but are almost always difficult to extract. At the base, zone 2_a, the *Malocystites murchisoni* zone, is well developed, and as the fossils weather out in this locality, some 40 species have been listed.

While the rocks of this division usually afford poor collections, yet in favorable localities they are found to be extremely rich in interesting species. Thus, one locality on the east side of the island has yielded 60 species of fossils, among them such rare trilobites as *Asaphus marginalis*, *Isotelus ? bearsi*, and *Remopleurides canadensis*, and many species of pelecypods.

Division 3.—This is especially well developed on Valcour Island. Zone 3_a is exposed in two or three localities on the east side. Zone 3_b is best developed about Cystid Point, the southeast point of Valcour Island, and zone 3_c is exposed both east and west of Black River Point on the north end. The division is 172 feet in thickness and carries *Camarotoechia plena* throughout. The faunules given for zones 3_a, 3_b, and 3_c, are those found on Valcour Island.

*Crown Point Section.**

The section at Crown Point is 305 feet in thickness. At the base is a zone 25 feet thick in which the strata are sandstone and shale, and the only fossil is *Lingula brainerdi*. The remaining 280 feet are impure blue and grey limestone, usually very fossiliferous. Division 1 is absent.

Division 2.—The fauna characteristic of this division is found all through the section at Crown Point. The characteristic fossils—*Maclurites magna*, *Rafinesquina champlainensis*, *Plæsiomys platys*, and *Leperditia limatula*—are very abundant, and the whole expression of the fauna is that of the middle part of the section at Valcour Island and elsewhere. Brainerd and Seely assign the lower 48 feet to their Division A, and the upper 57 feet to Division C, but faunally the whole section belongs together. *Camarotoechia plena* is absent, as are also the other fossils characteristic of Division 3. The upper 3 feet of the section are a coarse limy sandstone, with *Plæsiomys platys*, *Camarella varians*, *Raphistoma stamineum*, and *Isotelus harrisi* in a layer a foot thick at the top.

Orwell, Vermont.

A short distance northeast of Orwell village is the most southern exposure of the Chazy. At that place there are about 60 feet of strata, the fauna of which indicates that they belong to Division 2. Another locality near by shows sandstone and shale at the base of the formation.

North of the International Boundary the various divisions can not be followed in the published lists, but this is due to the fact that no sections have been made in that region. The lists published by Billings, Logan, and Ami, of the Canadian Survey, however, do show that fossils characteristic of all three divisions are found in that region. The Champlain Valley fauna of the Chazy, which will be designated as the typical one, is found as far north as Joliette, 35 miles north of Montreal and

* For detailed description of this section, see Bull. Amer. Pal., vol. iii, No. 14, 1902.

85 miles north of Chazy. To the west it is found as far as Hawkesbury, 75 miles northwest of Chazy and 55 miles west of Montreal.

MINGAN ISLANDS REGION.

The fauna of the Chazy at Mingan Islands is very closely related to that of the typical Chazy of the Champlain Valley, as is shown by the following list of species common to the two regions:—

<i>Bolboporites americanus.</i>	<i>Orthoceras bilineatum.</i>
<i>Phylloporina incepta.</i>	<i>O. multicameratum.</i>
<i>Columnaria</i> ? ? <i>parva.</i>	<i>Pleisoceras jason.</i>
<i>Rafinesquina incrassata.</i>	<i>Pliomerops canadensis.</i>
<i>Camaratæchia orientalis.</i>	<i>Illænus globosus.</i>
<i>Camarella longirostris.</i>	<i>Eoharpes antiquatus.</i>
<i>C. varians.</i>	

OTTAWA VALLEY REGION.

The Chazy deposits of this region have been described in detail by Logan,* Ells,† and Ami.‡ The formation is not more than 200 feet in thickness, usually less, and is divided into two parts, the lower including shales and sandstones, and the upper, limestones. It outcrops in a narrow belt extending along the north and south sides of the Ottawa River, from Hawkesbury west to Arnprior, and is again exposed south of Ottawa, whence another narrow belt runs to Cornwall, where it again turns northward. West of Arnprior there are a few outliers of the same formation. One large one occurs at Allumette Island, north of Pembroke, and another 10 or 15 miles south of this and west of Renfrew.

The coarse character of the sediments at the base of the formation in this region points to very shallow water and shore conditions and a probable erosion interval between the end of Beekmantown time and the deposition of the strata of Chazy age.

The writer has studied the rocks of this area chiefly in the vicinity of Ottawa and Aylmer, and the fauna there represented seems to consist of about 25 species, only 7 of which occur in typical Chazy deposits. The fauna of the sandstone at the Aylmer region is quite different from that found in the overlying limestone, and for that reason a list is here given of the species found in each. An asterisk denotes that the species is found also in the typical Chazy:—

* Geology of Canada, 1863.

† Rept. Geol. Survey of Canada, 1899.

‡ Ibidem; also Trans. Roy. Soc. Canada, vol. ii, 1896, vol. vi, 1900, and various other papers.

Sandstone.

- Lingula lyelli*.
 * *Camarotoechia plena*.
 * *C. orientalis*.
Hebertella imperator.
Modiolopsis breviscula.
M. parviscula.
M. sowteri sp. nov.
Ctenodonta parvidens sp. nov.
Whitella canadensis sp. nov.
 * *Archinacella* ? *deformata*.
 * *Raphistoma striatum*.
 * *R. stamineum*.
Lophospira billingsi sp. nov.
Bathyrurus angelini.
Beyrichia clavigera.
B. clavigera clavifracta.

Primitia sp.
Isochilina sp.

Limestone.

- Lingula lyelli*.
 * *Camarotoechia plena*.
 * *Rafinesquina alternata*.

Modiolopsis breviscula.
M. parviscula.

Raphistoma stamineum.
Orthoceras allumettensis.
Bathyrurus angelini.
Leperditia amygdalina.
 * *L. canadensis*.
Leperditella labellosa.
Isochilina ottawa.
I. amiana.
Primitia logani.

It may be seen from the above parallel lists that there are only 6 species common to the sandstone and limestone divisions of this formation. In the limestones the ostracods are exceedingly abundant, often making up entire layers of the rock. The two divisions are intimately connected by very well-defined species, however, and none of the forms pass on into the overlying Lowville limestone.

In the Ottawa Valley, the most noticeable feature of the faunas is the absence of the cystids, Bryozoa, and Hydrozoa so common in the typical Chazy. The large number of species of ostracods and their great abundance are in marked contrast to the three or four species found in the Champlain Valley. This difference in the lithology and fauna has led the writer to suggest the name *Aylmer** formation for these deposits in the Ottawa Valley.

SUMMARY ON THE LAKE CHAMPLAIN, MINGAN ISLANDS AND OTTAWA VALLEY REGIONS.

In the Lake Champlain region occurs the fullest development of both the strata and the fauna of the Chazy period, and three divisions based upon faunal differences may be recognized. The fauna of the Chazy at Mingan Islands, while only partly known, shows that the typical Chazy is also found in that region. West of Hawkesbury, Canada, a decided change

* Ann. Carnegie Mus., vol. iii, p. 380, 1905.

in the fauna is seen at L'Orignal, only 16 miles from Hawkesbury. Here is found a section less than 200 feet in thickness, with sandstone at the base and limestone in the upper portion. The fauna changes abruptly, several species occurring there which are unknown further east. The typical Chazy fossils found here are: *Camarotoechia plena*, *Raphistoma stamineum*, and *Malocystites murchisoni*. From this locality west to Allumette Island, a distance of 115 miles, the same succession of strata may be found, and about the same fauna. All through the Ottawa Valley the Chazy is represented by a formation which is sandstone at the base and limestone above. In its most western exposures, the limestones are absent and only the sandstone remains.

The base of the Chazy is always a sandstone, but this does not carry the same fauna in all regions, nor does the zone which rests upon it always have the same fauna. In the Lake Champlain region, the sandstone always contains *Lingula brainerdi*; in the Ottawa Valley, it carries a modified *Camarotoechia plena* fauna. At the type sections, *Lingula brainerdi* is at the base of the formation, while the *Camarotoechia plena* fauna appears 700 feet above.

Since the fullest development of limestone deposits of this age is in the region of Chazy and Valcour Island, New York, that must be the locality in which the Chazy sea persisted longest. From the evidence outlined above, it would seem that this sea was a shallow one, invading south and west over a slowly sinking land. Since the Chazy fauna is apparently developed less directly from the Beekmantown of the Lake Champlain area than from that of Newfoundland, and since there are many European types introduced into the Chazy, it seems probable that this sea was open to the east.

If the sea were thus invading upon the land, the sandstone would represent shore conditions. This is undoubtedly the case, for the sandstone in both the Champlain and Ottawa valleys frequently presents evidences of shore origin in cross bedding, ripple marks, and worm burrows.

If the sea were invading southward in the region now occupied by the Champlain Valley, the sandstone should be younger and younger in age as it is traced from north to south. That this is actually the case is shown by the faunas, for at Valcour Island all the strata of the *Hebertella exfoliata* division, 300 feet in thickness, were deposited before the *Maclurites magna* fauna became prominent, while at Crown Point this second fauna follows immediately upon the basal sandstone.

During the greater part of Chazy time, the transgression is southward, but later the shore began to move westward also. The region of the Ottawa Valley was then invaded, and the

sandstone brought with it a part of the *Camarotoechia plena* fauna. The date of this invasion to the west can be rather closely approximated. *Camarotoechia plena*, *Raphisoma stamineum*, and *Malocystites murchisoni* are found in the middle of the section at L'Orignal. At Valcour Island these species occur together in zone A₃, 775 feet above the base, thus showing that the formation in the Ottawa Valley represents the very latest part of Chazy time.

Ulrich and Schuchert, in their paper on Paleozoic Seas and Barriers,* bring out this idea of a Chazy sea invading westward and southward. They state: "With the earlier part of this subsidence [the Chazy invasion], the Atlantic invaded the continent westward. . . . The typical Chazy formation . . . bears evidence in its members of having encroached southward and westward in the arms, the latest beds . . . extending farthest south and west."

THE CLOSING PERIOD OF CHAZY TIME.

In the preceding pages an effort has been made to show that in northeastern New York and in the Ottawa Valley, the Chazy sea invaded over a land surface of Beekmantown rocks, and that the base of the Chazy is a tangential sandstone; also that the invasion was first southward, covering the region of the Champlain Valley, and later westward along the locality of the present Ottawa Valley.†

Of the former extent of the formation throughout the St. Lawrence Valley or elsewhere, there is at present little evidence. Since the sea did not attain the region of Aylmer until very late Chazy time, it is probable that the formation never extended much further west than the known outcrops in that region (Allumette Island, etc.).

From a study of the stratigraphy and faunas it becomes evident that the upper portion of the Chazy is not represented in the region south of Valcour Island. Either these beds were never deposited there or they were eroded before the Lowville was laid down. The evidence is not of such a character as to prove definitely which did occur, but for reasons given below it seems more probable that the upper beds were deposited south of Valcour and later eroded. These reasons are as follows:—

* Rept. N. Y. State Pal., 1902, p. 639.

[† By these terms, Champlain Valley and Ottawa Valley, the writer does not intend to convey the impression that the Chazy deposits were laid down in narrow arms of the sea, or that the topography was then anything like that of the present time. It should be remembered that strata of post-Chazy age are involved in the Green Mountain uplift, and that there are indications that the Adirondacks did not exist in Ordovician time.]

First. All through the Champlain Valley, the Chazy is capped by a bed of sandstone 2 feet in thickness, and this may be interpreted as the invading base of the Lowville formation. From this it would follow that a period of erosion existed between the Chazy and Lowville formations.

Second. If the upper beds were never deposited south of Valcour, the Chazy sea after advancing slowly to the south to some point below Orwell, Vermont, must have then retreated to the northward. Such a recedence could have been caused only by an elevation south of Orwell, for there is no general retreat of the Chazy sea at this time, which is proved by the fact that at a still later period the sea advanced westward beyond Ottawa. That there was then no uplift in the south is shown by the fact that the Lowville sea invades from the south-west.* On the other hypothesis, which seems more probable, the sea would have invaded southward to the region of Orwell and after depositing there the final, or *Camarotoechia plena*, beds vanished from the area of Lake Champlain. During the latter part of Chazy time or after its close, the Stones River (Lowville) sea was invading from south to north and there was a land interval in the Champlain region, during which time some of the Chazy and Beekmantown beds were removed along the barrier region between Orwell and the Mohawk Valley.

Third. By taking the rate of decrease in thickness (11.25 feet per mile) of the *Hebertella exfoliata* division between Chazy and Valcour Island, to compute the probable southern extent of that division, it is seen that it would have reached only 26.6 miles south from Valcour Island. Therefore, at the same rate of decrease the base of the Crown Point section is 461 feet higher than the base of the Valcour Island section. That this rate of decrease can not be used, is shown by the fact that Division 1 at Isle La Motte is only 225 feet thick, which is less than at Valcour Island, while Isle La Motte is as far north as is Chazy. The only reliable data for an estimate of this character are the facts that there are 300 feet of the beds of Division 1 at Valcour Island and nothing at Crown Point. This is a thinning out of 7.3 feet per mile, which, on the other hand, is probably too small. On this basis, the bottom of the Crown Point section is at least 300 feet above the base of the Valcour Island section and the base of the Orwell section is at least 424 feet above it. If this minimum estimate of the height of the base of the Crown Point section above that of the Valcour Island section is accepted as a working basis, it will be seen that the former lacks the upper 285 feet of the formation. This is a gradient of 6.95 feet per mile

* See Ulrich and Schuchert.

to the top of the beds at Valcour Island. Taking the base of the Orwell section at 424 feet, the upper 407 feet are lacking. The thinning in the 17 miles from Crown Point to Orwell is 122 feet, or 7.1 feet per mile, while the gradient to the top of the Chazy at Valcour Island is 7.01 feet per mile. The close correspondence of these gradients and the small gradient of 7 feet per mile for 58 miles are significant, and seemingly indicate a base-leveled surface of this land during the Chazy-Lowville interval.

REPRESENTATION OF CHAZY TIME IN OTHER REGIONS.

The Chazy was formerly identified by various geologists as covering a large area, but more recently it has been held that while certain formations may have been laid down during Chazy time, the typical rocks and fossils of this period are restricted to the region of the Champlain and Ottawa valleys and the islands in the Gulf of St. Lawrence.

The St. Peter's Sandstone.

One of the formations which has long been correlated in time with the Chazy is the St. Peter's sandstone, which in Iowa, Minnesota, and parts of Illinois underlies the lowest member of the Mohawkian series. The fauna* of this formation is meagre and is contained in a few layers near the top. It is made up chiefly of Mollusca, all closely allied to Trenton forms. None of the species are found in the Chazy; hence no new light is thrown on the correlation by the later studies of the Chazy fauna. On lithological grounds, James has correlated it with the Chazy of the Ottawa Valley, but there are no species common to the two formations. From the close relationship of its fauna to that of the Mohawkian (Trenton) it seems probable that the St. Peter's was deposited during Stones River time.

Stones River Group.

In the Columbia, Tennessee, folio of the U. S. Geologic Atlas, Ulrich has stated that the lower part of the Stones River group, including the Lebanon, Ridley, Pierce, and Murfreesboro limestones, is to be correlated in time with the Chazy of New York State.

This statement is evidently based mainly on stratigraphic grounds, as Ulrich and Schnichert† have held that the Low-

* F. W. Sardeson, Bull. Minnesota Acad. Sci., vol. iv, No. 1, pt. 1, p. 64, 1896.

† Paleozoic Seas and Barriers, Rept. N. Y. State Pal.; Bull. 52, N. Y. State Mus., 1902, p. 633.

ville of New York is the northeastern representative of "the extreme top of the Stones River" group.

In the Columbia folio referred to above, Ulrich has tabulated the fossils of all the divisions of the Stones River group as developed in the middle Tennessee region. In the Lebanon formation, the upper member of the Stones River group which is there correlated with the Chazy, there are, according to the table, 37 species besides 10 undescribed Bryozoa. Of these 37 species, 7 are Bryozoa and 5 are not specifically identified. This large number of Bryozoa—17 species—at once suggests that the formation containing them is much more closely allied to the Trenton than to the Chazy. Leaving out of account the Bryozoa, which in the Ordovician nearly always have a very restricted vertical range, and the 5 forms not specifically identified, it is found that 17 of the 25 species remaining are Black River or Trenton forms. All the brachiopods, 4 of the 5 gastropods, and 2 of the 3 trilobites are species occurring in higher formations. Even if all the described species are included, 53 per cent of the species of the Lebanon formation are Black River or Trenton forms.

Below the Lebanon is the Ridley horizon, about 80 feet in thickness. Of the 9 species listed from this formation, 6 are found in the Black River.

Below the Ridley is the Pierce limestone with 12 species listed and 20 undescribed bryozoans. Only 11 forms are specifically identified and of these 30 per cent are Black River or Trenton forms.

The lowest member of the Stones River group is the Murfreesboro, which is about 60 feet in thickness and contains 24 species, 21 of which are identified. The fauna is composed principally of Mollusca, of which gastropods of the genera *Lophospira* and *Liospira* are particularly numerous. Of the 21 species, 11 are Black River or Trenton forms, so that 52 per cent of the species in this oldest member of the Stones River group belong to the Black River or Trenton.

This analysis may be tabulated thus:—

	Lebanon.	Rid- ley.	Pierce.	Murfrees- boro.	Black River.	Tren- ton.
Lebanon	25	--	1	--	4	7
Ridley	1	3	--	--	1	1
Pierce	4	2	9	1	1	2
Murfreesboro.....	3	4	1	21	4	7

Of the 58 described species occurring in these 4 subdivisions of the Stones River, the above table shows that 27, that is, 46 per cent, occur in the Black River and Trenton formations.

Comparing the large percentage of forms common to the Stones River and to the Black River and Trenton with the low percentage—less than 5 per cent—of forms common to the Chazy and Trenton, it becomes evident that the Stones River and Trenton are faunally much more closely connected than are the Chazy and Trenton. This close relationship of the fauna of the Stones River to that of the Trenton, coupled with the stratigraphy, suggests that the whole Stones River is younger than the Chazy.

East Tennessee.

In east Tennessee the Maclurea limestone was correlated by Safford* with the Chazy or Black River of New York and Canada. While a large part of this limestone seems to be of Trenton age, a section around Lenoirs has afforded the writer a small fauna containing fossils characteristic of Division 2 in the Lake Champlain region. This region needs further study before definite correlations are made.

DESCRIPTION OF NEW SPECIES.

BRACHIOPODA.

Lingula columba sp. nov.

Shell small, oval in outline, gently and uniformly convex. There are no flat slopes and the front is semi-circular in outline. The posterior end is somewhat triangular, the beaks pointed. The surface is covered by very numerous and prominent concentric striæ, no radiating lines showing except when the surface is exfoliated.

One specimen is 10^{mm} long and 7^{mm} wide; another is 7^{mm} long and 5^{mm} wide.

Locality.—East side of Valcour Island at Chazy, and on Isle La Motte. Type in Yale University Museum.

Camarotoechia pristina sp. nov.

Shells small, transversely oval to subcircular in outline. Both valves moderately and uniformly convex. The dorsal valve has a low fold and the ventral valve a shallow sinus, which is noticeable only toward the front of the shell. There are 10 to 14 strong rounded plications, 4 on the dorsal fold and 3 on the sinus. The 2 plications in the middle of the fold are smaller than the 2 outside ones and the median plication of the ventral valve is the weakest, which is the direct opposite of the state found in *Camarotoechia orientalis*.

Locality.—Valcour Island and Chazy, New York. The type is in the Carnegie Museum.

* Geol. Tennessee, 1869, p. 236.

Camarotoechia major sp. nov.

Outline somewhat oval, widest a little in front of the middle. Dorsal valve with 10 to 14 strong angular plications. The ventral valve has 9 to 14. The fold and sinus are hardly defined except by a gentle arch in front, but are outlined on both valves by a pair of very strong plications. The dorsal fold bears 5 plications, the middle one of which is the strongest. The ventral sinus has 4 plications, the 2 largest in the middle. The ventral beak is somewhat incurved.

Length of a good specimen 23^{mm}; width 21^{mm}.

Locality.—Southeast point of Valcour Island, New York. The type is in the writer's collection.

Strophomena prisca sp. nov.

Shell of medium size, resupinate, nearly as long as wide. Ventral valve convex at the umbo, flat in front to about the middle of the valve and then concave. Dorsal valve flat on the umbo and convex in front. Cardinal area narrow, the wide delthyrium mostly covered by the deltidium, with a small opening for the pedicle at the beak. Muscle area in the ventral valve small, confined to the space under the umbo. Surface marked by fine alternating striæ, the prominent ones being very numerous and increasing by implantation. Between each pair of the strong striæ are two or three finer ones and the whole surface is crenulated by fine concentric striæ. The dorsal valve sometimes shows very small concentric wrinkles.

One specimen is 15.5^{mm} long and 20^{mm} wide; another 16^{mm} long and 19.5^{mm} wide.

Locality.—All the specimens are from Valcour Island, New York, and are in the writer's collection.

Orthis ignicula sp. nov.

Shell transversely oval in outline, usually but little wider than long. Hinge width nearly equal to the greatest width of the shell. Ventral valve strongly convex, the area high and a little incurved.

Dorsal valve nearly flat, with a broad depression near the front. Area of dorsal valve rather wide. Cardinal process small. Delthyrium narrow and open. Surface marked by 16 to 25 direct rounded plications which increase by implantation.

Locality.—Found rarely on the southeast corner of Valcour Island, New York.

Orthis acutiplicata sp. nov.

Shell small, almost circular in outline. Hinge width not quite equal to the greatest width below. Cardinal area of ventral valve high and a little retrorse. Foramen narrow and open. Ventral valve strongly convex, highest on the umbo. Dorsal valve convex on the umbo, flattened in front. There is a shallow sinus on this valve, which is narrow at the beak but becomes wider in front. Surface marked by 12 to 15 sharp simple striæ separated by spaces wider than the striæ.

Locality.—South end of Valcour Island. The types are in the writer's collection.

Plæsiomys strophomenoides sp. nov.

Shell small, ventral valve convex at the umbo, concave in front. Dorsal valve convex, with a narrow sinus on the umbo, but frequently with a slight fold on the front of the shell, in which case the ventral valve shows a shallow median sinus.

Surface marked by numerous fine striæ, which increase by bifurcation and implantation. There are usually 7 or 8 in the space of 2 millimeters on the middle of the front of the shell.

The cardinal area of both valves is low. The ventral area has a narrow delthyrium, which at the apex is perforated for the passage of the pedicle. The interior of the ventral valve shows small but strongly marked muscle scars under the umbo. The muscle area is roughly quadrate and contains a pair of strong diductor scars, between which are the narrow adductor attachments. Posterior to the latter is a deep pedicle scar. The lateral edges of the diductor scars are bounded by strong plates, which run back to support the dental lamellæ. The interior of the dorsal valve shows a robust, simple cardinal process and small dental sockets bordered by strong plates which do not greatly diverge. In front of the cardinal process is a low but strong median ridge, on either side of which are the four scars of the adductor, not, however, deeply impressed.

Locality.—Crown Point, Plattsburg, and Valcour Island, New York. The type is from the quarries near the Plattsburg Fair Grounds and is in the Carnegie Museum.

Hebertella exfoliata sp. nov.

This shell is distinguished from *Hebertella costalis* by its smaller size, more pronounced dorsal sinus, and by the fact that the striæ are always simple instead of bifurcating. It differs from *H. borealis* in its smaller size, and in the narrow and deep dorsal sinus.

Locality.—Common in the lower part of the Chazy at Chazy and Valcour Island; also at Plattsburg, Valcour, and Isle La Motte, New York. The type is in the Carnegie Museum.

Orthidium lumellosa sp. nov.

Ventral valve strongly convex, the area high and curved backward. Delthyrium narrow and open. Along the middle of the valve is a narrow and shallow depression in which there is one plication. The outline of the shell is subquadrate. The greatest length is at the hinge and the cardinal extremities are slightly alate.

The dorsal valve has a narrow median sinus, which extends from the beak to the front and usually contains 2 plications. There are commonly about 20 sharp plications, which are crossed by strong concentric lamellæ of growth.

An average specimen is 3^{mm} long and 5.5^{mm} wide.

Locality.—Valcour Island, Chazy, and Crown Point, New York. The types are in the Yale University Museum.

PELECYPODA.

Ctenodonta peracuta sp. nov.

Shell small, longer than high, the beak about one-third the length from the posterior margin. Front rather drawn out, as in *Ctenodonta nasuta* Hall. The greatest convexity is at the umbo, the posterior slope very gradual. Both slopes to the hinge abrupt, but that to the basal margin gentle. One specimen is 12^{mm} long and 9^{mm} high. This species may be distinguished from the succeeding one by its more depressed valves and by the prolongation of the anterior margin into a somewhat nasute extension.

Locality.—Found in some numbers in the trilobite layers at Sloop Bay, Valcour Island, and in the middle of the Crown Point section. The type is in the writer's collection.

Ctenodonta limbata sp. nov.

Outline nearly circular, the beak back of the middle. Greatest convexity near the middle of the valve; all slopes steep. The cast shows a few faint lines of growth.

Length of largest specimen 10^{mm}; height 10^{mm}. A smaller one measures 8 x 8^{mm}.

Locality.—All the specimens are from the trilobite layers, Sloop Bay, Valcour Island. The types are in the Yale University Museum.

Ctenodonta dubiaformis sp. nov.

Shell small, moderately convex, beak subcentral. Greatest convexity on the umbo, the slope from it to the base nearly flat. Basal margin nearly straight. Anterior end nasute and

longer than the posterior, which is regularly rounded. Front margin rather acute. All the specimens are of casts without trace of hinge teeth, muscle scars, or surface markings.

Largest specimen: Length 19^{mm} ; height 10.5^{mm} . Another: Length 17^{mm} ; height 9^{mm} .

Locality.—Sloop Bay, Valcour Island. The type is in the Yale University Museum.

Otenodonta parvidens sp. nov.

Shell oval in outline, usually flattened, but specimens from the harder layers show considerable convexity below the umbo, with regular slopes to the anterior, posterior, and ventral margins. The cast shows the impression of numerous very fine teeth on the hinge, but the number can not be counted as the beak is always flattened down upon the impression of the hinge. One specimen exhibits 5 teeth on the anterior portion of the hinge. Another shows 7. The surface is marked by very numerous fine concentric lines of growth.

Locality.—In shales and limy clays at the Hog's Back, Ottawa.

Clidophorus obscurus sp. nov.

Shell small, longer than high, not very convex. Basal margin nearly straight, anterior margin regularly curved, posterior end compressed, the margin acutely rounded. In front of the beak the cast shows a short clavicular impression, which extends about half the distance to the lower margin.

Length 6^{mm} ; height 4^{mm} .

Locality.—Trilobite layers, Sloop Bay, Valcour Island. The type is in the Yale collection.

Cyrtodonta tranceps sp. nov.

Shell roughly rectangular in outline, strongly convex at the umbo and along a ridge which runs diagonally across the shell to the lower side of the posterior margin. In front of this ridge there is usually a slight depression running from the umbo to the middle of the lower side. The posterior margin is regularly rounded, the lower side straight or slightly indented. The anterior end extends a short distance in front of the beak. The slope to the hinge is flat and rather steep. The slope to the front and base is gently convex and more gradual. The surface is marked by numerous concentric lines.

Locality.—Valcour Island, New York. The type is in the collection of the Carnegie Museum.

Cyrtodonta solitaria sp. nov.

Shell roughly triangular, the beak a little behind the anterior end. Hinge line short. The anterior margin is narrow and rounded, the base long and straight, incurved at about 45° with the hinge. Posterior regularly rounded. Shell only moderately convex, the slope to the posterior end gradual and to the front nearly flat.

Length 15^{mm} ; height 12.5^{mm} . Surface marked by concentric lines of growth.

Locality.—Ledge in pasture near Tracy Brook, Chazy, New York. The type is in the Yale collection.

Whitella canadensis sp. nov.

Shell small, convex, subrectangular in outline. A prominent ridge extends from the beak to the lower posterior corner. From this ridge the slope to the cardinal and posterior margins is abrupt, while there is little slope to the front until a point in front of the beak is reached, when the slope is suddenly deflected. The surface is marked by concentric undulations.

Locality.—Aylmer sandstone, Aylmer, Quebec.

Clionychia marginalis sp. nov.

Both valves moderately convex, the umbones somewhat depressed, but increasing rapidly in height, the greatest thickness of the valves being at about one-third the distance from the beak to the lower margin. Hinge line short. The posterior margin is broadly rounded, the lower margin semi-circular. The front is almost straight. The greatest convexity is along a line parallel to the front. The posterior and lower slopes are gentle, but the front slope is abrupt, almost 90° with the plane of union of the valves. The surface is marked by very fine concentric striæ.

One specimen is 20^{mm} long and 26.5^{mm} high.

Locality.—Chazy and Valcour Island, New York. The type is in the Yale collection.

Ambonychia? curvata sp. nov.

Shell large, both valves very strongly convex, especially along the region of the front and middle of the valves. Beaks small, incurved, directed a little forward. Anterior slope abrupt and overhanging. Posterior and bottom slopes rather steep. Posterior wing short. The posterior margin is almost straight. The anterior margin is regularly curved. The length and breadth are nearly equal.

A large specimen is 27^{mm} long and 26^{mm} high. Another is 43^{mm} long and 39^{mm} high. A small one is 10^{mm} long and 10^{mm} high.

The species is easily recognized by the curved anterior margin and the great convexity. The line of greatest convexity follows the anterior margin. There is an elongate posterior muscle faintly outlined on some of the casts. The general appearance is somewhat like *Ambonychia amygdalina* Hall.

Locality.—Valcour Island, Chazy, and Sloop Island, New York.

Conocardium beecheri sp. nov.

Shell very small but robust, with long anterior and short posterior wings. The region of greatest convexity is from the beak straight to the base of the shell, the curvature decreasing gradually forward to the anterior wing and rather abruptly backward to the posterior wing. The anterior wing is long, with straight lower margin. The posterior wing is short and narrow, joining the body at a large angle. The surface is marked by 7 or 8 large plications on the anterior wing, 15 or 20 smaller ones on the body of the shell, and 3 or 4 very large ones on the posterior wing. The dimensions of 2 specimens are: First, length 6.5^{mm}, height 5^{mm}; second, length 6^{mm}, height 4^{mm}.

Locality.—Sloop Island, east of Valcour Island, New York; also on Valcour Island and at Chazy, Clinton County, New York.

Modiolopsis fabaformis sp. nov.

Shell small, thick, with a strong ridge extending from the umbo to the lower posterior angle. In front of this ridge is a deep depression, which continues to the middle of the ventral margin, making that margin sinuate. Anterior ear small, convex. Anterior margin narrowly rounded. Posterior margin broadly rounded, not oblique as in *Modiolopsis breviuscula* and *M. parviuscula*. The surface is marked by numerous concentric lines of growth.

Locality.—Common in the upper layers at Valcour Island. The type specimen is in the writer's collection.

Modiolopsis sowteri sp. nov.

Shell of medium size for the genus, rather convex, with a strong ridge running back from the beak to the lower posterior angle. Toward the front is a slight depression running from just ahead of the beaks a little backward to the basal margin. In front of the beak is a very deeply impressed anterior scar,

which on the internal cast is represented by a rounded conical elevation. The posterior scar is large and close to the hinge line.

Length 51^{mm}, height 28^{mm}.

Length 37^{mm}, height 20^{mm}.

Locality.—From the Aylmer sandstone, about 60 feet above the high-water mark of Lake Deschenes, at Aylmer, Quebec. Collected by T. W. E. Sowter, for whom it is named. The type is in the Yale University Museum.

GASTROPODA.

Archinacella? deformata (Hall).

Orbicula? deformata Hall, 1847, Pal. N. Y., vol. i, p. 23, pl. iv bis, figs. 10a, 10b.

Metoptoma? dubia Hall, *ibid.*, figs. 11a, 11b.

Stenotheca dubia Whitfield and Hovey, 1898, Catalogue of Type and Figured Specimens in the American Museum of Natural History, Bull. Amer. Mus. Nat. Hist., vol. xi, p. 58.

An examination of the types shows that Whitfield was right in regarding the specimen named *Orbicula? deformata* by Hall as identical with *Metoptoma? dubia*, which Hall described on the same page. His species, however, must take the first specific name applied to it, even though given under the misapprehension that it was a brachiopod instead of a gastropod.

The generic reference is uncertain as no specimens have been found which show either muscle scars or pronounced surface markings. It does not seem possible to leave it either in the genus *Metoptoma*, where Hall doubtfully put it, or in *Stenotheca*, where it was placed by Whitfield. In general form it most resembles the numerous species of *Archinacella* described by Ulrich and Scofield, to which it may be referred until better examples are obtained. The individual specimens of this shell are abundant and the characters are quite constant. It is easily recognized by the low form and almost marginal position of the beak.

Scenella pretensa sp. nov.

Shell small, aperture narrowly elliptical in outline. Height about equal to the greatest diameter of the aperture. Beak small, pointed backward, but not incurved. Posterior slope nearly straight. Anterior slope convex above, becoming straight below. Surface smooth, except for a few low concentric undulations near the base. Beak a little behind the middle.

The greatest diameter is 11^{mm}; the shortest is 6.5^{mm}. Height 11.5^{mm}.

Locality.—Rare at Chazy, New York, in the Lower Chazy layers south of the lime kilns. It occurs also at Lenoirs, Tennessee.

Scenella robusta sp. nov.

Shell large, aperture nearly circular. Beak obtuse, rather high, and located a little behind the middle. All slopes about equal and all convex, the whole shell somewhat hemispheric. The specimens are all casts, showing no surface markings of any sort.

The only perfect example is 17^{mm} in greater diameter and 16^{mm} in lesser. A much larger one is represented by a fragment 27^{mm} long, but it had evidently been considerably larger.

Locality.—Valcour Island, in the Middle Chazy beds. Rare. The type is in the writer's collection.

Palæacmæa irregularis sp. nov.

Shell rather large, irregular in outline, generally subcircular, but never with a smooth curve. Beak obtuse, almost central, sometimes a little back of the center. All slopes about equal, generally almost straight, but occasionally a little convex. Surface marked by numerous fine concentric lines of growth, which follow the irregular form of the aperture. Usually there are a few radial folds and some irregular depressions and pits which do not follow in symmetrical arrangement.

The greater diameter of the aperture is 26^{mm}; the lesser is 10^{mm}. The aperture of another is 19^{mm} long, 18^{mm} wide, and the apex is 9^{mm} above the aperture.

Locality.—Common in lower layers at Chazy, New York.

Helicotoma vagrans sp. nov.

Shell small, somewhat *Maclurea*-like, the spire flat and depressed below the plane of the highest points on the upper surface. Outer edge of the body whorl angular, raised as a high sharp ridge toward the aperture. Lower surface of the shell rounded, the umbilicus wide. Aperture large, quadrilateral, angular above, rounded below. Surface marked by fine lines of growth, which turn back on crossing the angle of the upper surface.

Locality.—A rare fossil at Valcour Island, New York. The type is in the writer's collection.

Eotomaria obsoletum sp. nov.

Shell small, trochiform, with about four volutions. The upper part is conical, the volutions are flat, and the sutures only

slightly impressed. The lower surface is convex, umbilicus small. The present specimen is a cast and shows no surface markings. Aperture large, angulated on the side, rounded below.

Locality.—Crown Point and Valcour Island, New York. Very rare. The type is in the writer's collection.

Lophospira rectangularis sp. nov.

Shell fairly large, with 5 volutions. Body whorl very large, spire small. Last 3 whorls with sides parallel to the axis of the shell. Aperture large, nearly circular. Upper lip nearly straight, meeting the straight outer lip at an obtuse angle. The inner and lower sides of the aperture are rounded. The umbilicus is very small.

All the specimens in the collection are casts of the interior and do not show anything more than traces of the surface markings. They were probably the same as in *Lophospira subabbreviata*.

Locality.—A rare species from Valcour Island, New York. The type is in the writer's collection.

Lophospira billingsi sp. nov.

Shell of 4 volutions, body whorl very large, spire low, whorls angular, sloping gently from the suture to the keel. The under side of the body whorl is rounded and strongly convex. The umbilicus is small. The aperture is entire, the inner and lower lips are rounded, the upper lip is straight from the suture to the keel, sharply angulated at the keel and nearly straight for a short distance below it. The surface is covered by rather coarse lines of growth, which run first forward and cross the upper side of the volution diagonally and backward, again turning forward after crossing the volution. On the under surface of the whorl, the striæ turn back to the umbilicus.

Locality.—From the Canadian Pacific Railroad cut, east of Main street, Aylmer, Canada. Named for W. R. Billings of Ottawa, an enthusiastic student of the Chazy.

Cyclonema? normaliana sp. nov.

Shell small, elongate trochiform, with 4 or 5 whorls, which enlarge gradually. Sutures not deeply impressed and volutions almost flat sided. The under surface of the last whorl is flat or slightly convex. The surface is marked by 3 or 4 revolving raised lines or low keels.

Locality.—Lower Chazy, near the Normal School at Plattsburg, New York.

Eunema leptonotum sp. nov.

Shell small, with about 4 whorls, which increase gradually toward the base. The whorls are all convex, the suture is deeply impressed. The first 3 whorls are smooth and *Holopea*-like. The fourth, or body, whorl is ornamented by 5 sharp revolving ridges, equally spaced. These ridges are crossed by fine vertical lines, which are close together and give the ridges a pitted appearance. The aperture is not seen.

The height of the shell is 5^{mm}; the width of the body whorl 3.5^{mm}.

This shell is not uncommon in the Chazy, but on account of its small size and liability to exfoliation it is often overlooked or is in too imperfect a condition to be positively identified.

Locality.—Lower Chazy, at Chazy, New York. The type is in the Yale collection.

Trochonema dispar sp. nov.

Shell rather large, consisting of 3 whorls with depressed spire and very large body whorl. The suture is very deep. The whorls are almost free. The body whorl has a flat revolving band on the outer side. The top is flat and sloping and the lower side strongly convex. The surface markings are not shown. The umbilicus is large in the cast, but rather small in testiferous specimens.

Locality.—Fairly common on Valcour Island, in a locality at the south end. It is rare elsewhere on the island and at Chazy, New York. The type is in the writer's collection.

Subulites prolongata sp. nov.

Shell small, elongate, fusiform, with about 6 (?) whorls (specimen shows body whorl and 3 above). The whorls are long and narrow, decreasing slowly and regularly toward the top. The body whorl is about equal to the length of the 2 whorls above it and is contracted below. The aperture is not shown.

The length of the fragment is 29^{mm}; the greatest thickness is 5^{mm}. Probably the total length was about 35^{mm}.

Locality.—Sloop Bay, Valcour Island. The type is in the Yale collection.

Holopea hudsoni sp. nov.

Shell usually large, with about 4 whorls. The body whorl is large, robust, expanding rapidly. The spire is fairly long, whorls strongly convex, sutures very deep. Aperture nearly circular, entire; the outer lip thin, the inner lip free from the body whorl. The umbilicus is small.

The surface is usually smooth. Some casts show traces of lines parallel to the margin of the outer lip. These lines run a little forward from the suture, continuing in this direction over the bulge of the whorl, then curve a little backward and finally forward again at the lower end.

Locality.—Rather common at Crown Point, Valcour, Valcour Island, Plattsburg, and Chazy, New York. The type is in the writer's collection.

Holopea scrutator sp. nov.

Shell of medium size, about 3 whorls, the body whorl constituting by far the larger part of the shell. Spire depressed, sutures not deep. Aperture elongate, oval, entire. Umbilicus small.

The specimens usually occur as casts, but on a few the shell is preserved. It shows no markings except a few growth lines, which run diagonally back across the whorl. When the specimens are exfoliated the suture lines are much more deeply impressed and the spire appears higher.

This shell is easily distinguished from the preceding by the low spire, the shallowness of the sutures and the general depressed form of the shell.

Locality.—Common at Valcour Island and Chazy, New York. The type is in the Yale Collection.

Conularia triangulata sp. nov.

Shell small, slender, slightly curved, 6-sided, but 3 of the sides are so narrow as to give the shell an almost triangular cross section. The narrow faces alternate with the wide ones, the former truncating the angles which the latter would make if prolonged till they met. Along each of the faces, both wide and narrow, is an elevated line, which extends longitudinally along the center of the face. The surface markings consist of numerous fine transverse striae, which bend backward on crossing the raised line.

The best specimen in the writer's collection is broken at the tip and at the aperture, yet is 38^{mm} long. The original length was at least 8^{mm} more. At the largest end the 3 wide faces are each 7^{mm} wide and the narrow faces are each 1.5^{mm} wide. At the small end the wide faces are 2.5^{mm} wide and the narrow faces are reduced to practically nothing, thus showing that in young stages the shell was really triangular.

Locality.—The type specimen, which is in the writer's collection, was found in the upper part of the Chazy, on the southeast point of Valcour Island (Cystid Point). It also occurs near Smuggler's Bay, in layers a little lower in the formation.

OSTRACODA.

Leperditia limatula sp. nov.

Length 10.5^{mm}; height 7.5^{mm}.

Length 9^{mm}; height 6^{mm}.

Length 9.5^{mm}; height 6.25^{mm}.

Length 9.5^{mm}; height 7.5^{mm}.

Shell of medium size, a little smaller than *Leperditia fabulites*, oblong in outline, higher behind than in front. Hinge short, straight. Anterior end regularly rounded. The posterior end slopes back almost straight for a short distance, but is broadly rounded on the lower posterior margin. The eye tubercle is small, on some specimens sharp, on others obscure. It is situated in the anterior angle, above and a little in front of the "muscle spot." The latter is large, circular, and very finely reticulated. Back of the muscle spot is a region of the shell which is covered with fine raised lines radiating from the side of the spot. These lines frequently anastomose, making a very pretty reticulate surface. The muscle spot is raised above the general surface of the carapace on the lower posterior side, where these lines originate, but the upper and anterior sides are level with the main part of the shell.

The right valve overlaps the left valve considerably, especially along the ventral edge, which is abruptly deflected and usually shows a low short ridge right at the keel. The lower margins of the anterior and posterior ends are flanged. The border is very narrow and is marked by small pits, which increase in size ventrally. On one finely preserved specimen the anterior flange shows 8 pits, of which the seventh, counted from the front, is largest, and the eighth is very small. On the posterior flange of the same specimen there are 10 pits, the eighth from the posterior end being the largest, the ninth a little smaller, and the tenth minute. The left valve is not so high in proportion to the length as the right valve, but it is also abruptly deflected ventrally. It shows neither anterior nor posterior flanges and there is a small projection close to the hinge line and parallel to it. Below this is a slight depression.

Locality.—Common on Valcour Island in certain localities. Rare at Valcour and Chazy, New York.

Primitia latimarginata sp. nov.

Carapace small and depressed. Front and posterior margins meet the dorsal margin at angles of little more than 90°. Both ends are broadly rounded, the ventral margin is gently curved. The shell is a little higher at the posterior end than

in front. There is a deep sulcus just in front of the middle, which starts from the dorsal margin and extends half-way down the valve, turning a little forward at the lower end. On well-preserved specimens, in front of this sulcus there is a prominent eye spot, which is sometimes translucent. Often there is another slight depression or sulcus in front of the eye spot. The border is wide, concave, and of nearly uniform width all around from the anterior angle of the dorsal margin to the posterior one. The test is frequently punctate.

Locality.—Common all through the Chazy limestone at Chazy, Valcour Island, Crown Point, and elsewhere in the Champlain Valley.

TRILOBITA.

Helimera subgen. nov.

Helimera sol (Billings).

Cheirurus sol Billings, 1865, Paleozoic Fossils of Canada, vol. i, p. 288, fig. 276.

Cephalon short, wide, the glabella very large and flattened, the cheeks small. Glabella almost semi-circular, with 3 pairs of long, narrow glabellar furrows, all of which turn backward on their inner ends, each joining the one back of it, and the third pair joining the neck furrow, thus producing a central lobe like that of *Amphilichas*. This central lobe is of uniform width up to the inner ends of the first pair of glabellar furrows, but turns outward in front of that point. Toward the front of this median lobe there is a slight depression, somewhat similar to that sometimes seen in *Plimerops canadensis*. The first pair of glabellar furrows run backward at an angle of about 45°, the second pair at a smaller angle, while the third pair are nearly parallel to the neck furrow. The glabellar lobes are narrow and club-shaped. This radiating arrangement of the glabellar furrows and lobes probably suggested the specific name. The neck ring is wide, flat, and separated from the glabella by a deep furrow, which extends the whole width of the cephalon. The cheeks are not sufficiently well preserved to be described, but enough of the test remains to show that the outline of the cephalon was the same as in *Pseudosphærezochus vulcanus*. There is a narrow smooth border all around the front of the cephalon, and the surface is covered with fine tubercles. The relations of this species are rather doubtful. From the form of the cephalon it evidently belongs close to *Pseudosphærezochus*, but there has not been seen in species of that genus any tendency to vary in the direction of an isolated central lobe and long isolated glabellar

furrows. The glabellar furrows in the various species of *Pseudosphærexochus* are usually faint, never deeply impressed as in this species. In this last character and in the presence of the median depression of the glabella, it recalls *Plimerops*. The glabella is much larger in proportion to the size of the cephalon in *Heliomera sol*, however, and it is probable that this form must be regarded as intermediate between the two genera. For trilobites with this type of glabellar structure the subgeneric name *Heliomera* is suggested.

Locality.—From the Raphistoma layers in the upper part of the Lower Chazy, at Chazy, New York. The type is in the Yale University Museum.

Paleontological Laboratory,
Yale University Museum, June 24, 1905.

ART. XXXIX.—*The Mechanical Properties of Catgut Musical Strings*; by J. R. BENTON, PH.D.

THE experiments here described were made in connection with investigations on the stress-strain relation in elastic solids, carried out at the Geophysical Laboratory of the Carnegie Institution under the direction of Dr. G. F. Becker, to whom the writer desires to make acknowledgment for many valuable suggestions in regard to the work presented in this note. Researches on the stress-strain relation have been made for rubber and for the metals; and it was thought of interest to experiment also on a substance of intermediate properties as regards extension within the elastic limit; for this purpose, catgut, as used for strings of musical instruments, appeared to be best adapted. Owing to its hygroscopic properties and the complicated nature of the after-effects it exhibits, it was found that a precise determination of the deviations from Hooke's law would involve an amount of labor far greater than was thought to be warranted by the importance of the substance. Such results as were obtained, however, together with general data on the mechanical properties of catgut, seem of sufficient interest to justify the publication of the present note.

Tensile Strength.—A piece of catgut $\cdot 061^{\text{cm}}$ in diameter had an average breaking load of 12.0 kg., corresponding to a tensile strength of 43 kg. per mm^2 (60,000 lbs. per sq. in.). A piece $\cdot 038^{\text{cm}}$ in diameter broke under 4.5 kg., corresponding to a tensile strength of 41 kg. per mm^2 . These figures show that it is nearly as strong as copper wire, and must be classed as one of the strongest organic substances, far exceeding all kinds of wood (less than 20,000 lbs. per sq. in.), leather (5000 lbs. per sq. in.), and hemp ropes (15,000 lbs. per sq. in.).

Catgut musical strings, as furnished on the market, are twisted, and tend to untwist when subjected to tension, and to twist up again when tension is removed. In order to study their elasticity, this twist must be removed, which is accomplished by soaking the string in water. If hot water is used the string becomes very soft, and contracts greatly in length. In this condition it behaves very much like rubber; it can be stretched to nearly double its unstrained length, and when released it snaps back like a rubber band.

It is greatly weakened, however, by being wet; but it regains its strength more or less completely upon drying, as shown in the following table:

Catgut string, .038^{cm} in diameter.
Average breaking load before special treatment, 4.5 kg.

Number of tests.	Treatment.	Breaking load in kgs.
2	Soaked $\frac{1}{2}$ hr. in water at 30° C., then tested while wet	2.1
1	“ “ “ “ “ dried, then tested	5.0
2	Soaked 1 hr. in water at 30° C., dried for five days, then tested	4.3, 4.4
1	Soaked 5 min. in water at 90° C., then tested while wet	less than 0.5
4	“ “ “ “ “ dried, then tested	1.0–1.9

Elongation at Rupture.—A piece 0.062^{cm} in diameter, and 5.9^{cm} long, stretched to 7.0^{cm} just before rupture, or 19 per cent of its original length. Another test gave 15 per cent. These figures include whatever stretching was due to untwisting. After rupture the pieces were too much frayed out for any determination of their length.

Specific gravity.—By weighing a piece of catgut (not treated with water) of known length and cross section, its specific gravity was determined as 1.18 (± 0.01).

All the remaining experiments to be described were made on a violin E-string, 150^{cm} long and 0.062^{cm} in mean diameter (the diameter was not quite uniform, varying between 0.059 and 0.65). It was freed from its original torsion on August 20, 1904, by soaking one and a half hours in water of 30° C., and while drying it supported a load of 0.5 kg. The experiments were carried on from time to time during the following year, at intervals during the prosecution of other work.

Hygroscopic properties.—Upon setting up this string and sighting with a micrometer telescope at a point near its lower end, it was at once seen that the length of the string did not remain constant; and by observing at intervals and determining the humidity of the air at the same time, it was easily demonstrated that the string stretched when the dampness increased and contracted when it decreased. This is in accordance with the well-known tendency of violin strings to break in dry weather. When the weather is damp the string has to be tightened to maintain the tension to keep it in tune; with increasing dryness its tension increases until finally it snaps. The actual tension required on a violin E-string to produce the proper pitch of 640 vibrations per second may be computed from the length of string (about 33^{cm}) and its specific mass

(0.0035 g. per cm. of length) by the well-known formula for transverse vibrations of strings, and comes out about 6 kg., or about one-half of the breaking load. During the above experiments the string carried a load of 1.0 kg, and the temperature was 20 to 25° C. The order of magnitude of the changes was 0.0002 of the length of the string for each cm. of mercury of vapor tension. Precise determination of the dependence of length on humidity was made prohibitively difficult by the phenomena described in the following paragraph.

After-effects.—Whenever any change was produced in the conditions, the catgut did not at once come into equilibrium under the new conditions, but did so only gradually. Thus,

1

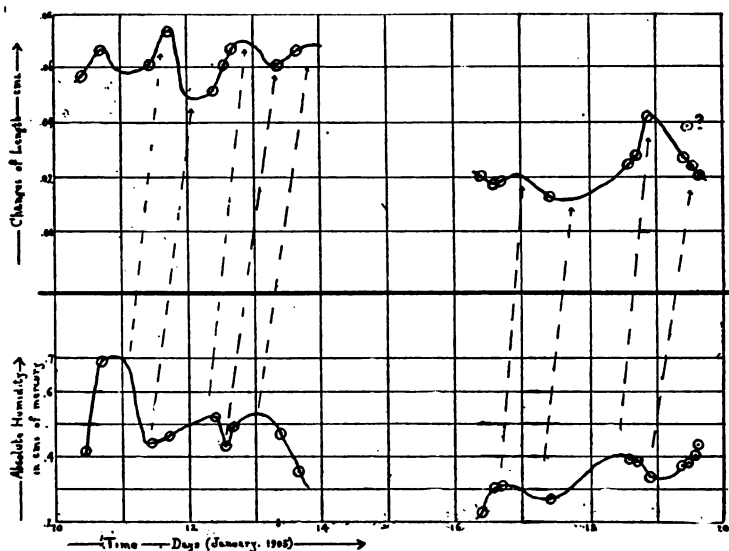
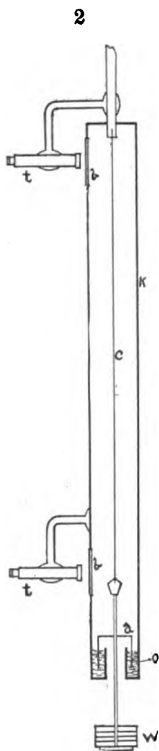


FIGURE 1.—Length and Humidity as Functions of Time.

when the load upon it was changed, it exhibited in marked degree the well-known elastic after-effect, requiring some days to come to sensible equilibrium, during which time the change in length due to change in load increased by about 25 per cent of its final amount. It was found also that the stretch due to humidity tended to continue after a change of humidity ceased; this could easily be seen in the fluctuations of humidity accompanying changes of weather; but no facilities for controlling humidity were available, and so no attempt could be made to study these phenomena thoroughly. No doubt some time is required for moisture to penetrate into the interior of the catgut. The curves of figure 1 represent change of length of the

catgut, and humidity (absolute), both as functions of time. After-effects were detected also in connection with change of temperature.

The elastic after-effect is of course responsible for the behavior of new strings on violins, which get out of tune very rapidly at first, and always in the direction of lower pitch. With greater duration of the tension the after-effect becomes less marked and the material approaches equilibrium under the imposed conditions. But if left for some time, the tendency is always towards lower rather than higher pitch, if temperature and humidity do not change.



To protect the string from changes of humidity, it was placed inside of a tube of galvanized iron ("spout-pipe"), 6 inches in diameter, and 2 meters long, the seam of which was soldered up (*k*, fig. 2). Near the top and bottom, plate glass windows (*b*, *b'*), $7\frac{1}{2} \times 15$ cm., were fastened into it and made moisture-tight by liberal application of thick grease ("mobilubricant") beneath the glass and around its edges. Inside the bottom of the tube a circular trough (*o*, fig. 2) 4 cm wide was soldered against it and filled with engine oil. A hanger was attached to the bottom of the catgut, and hung through the hole in the middle of the trough; to this hanger was fastened an inverted cup (*a*) of tin, which dipped into the oil of the trough. Thus the catgut was completely protected against changes of moisture in the air, and at the same time could be subjected to any desired tension by placing weights upon the hanger sticking out from the bottom of the tube. The whole arrangement was supported from the ceiling and braced against the floor. Micrometer telescopes for reading at top and bottom were supported from the tube itself. The top telescope took account of any sinking of the upper support; the distance between the two marks sighted upon on the string was 138 cm. The telescope at the bottom could be shifted bodily to keep up with stretching of the string; a reflection prism was fastened to it in front of its objective, and reflected into its field of view the image of a steel centimeter scale fastened vertically near by. In this way the shift of the telescope when moved could be measured.

Coefficient of Thermal Expansion.—After the catgut had been in the tube four days, readings were made upon it from

time to time, and were still found to fluctuate. Upon comparing these readings with those for temperature, it was obvious that the changes were related to it, as may be seen in figure 3;

8

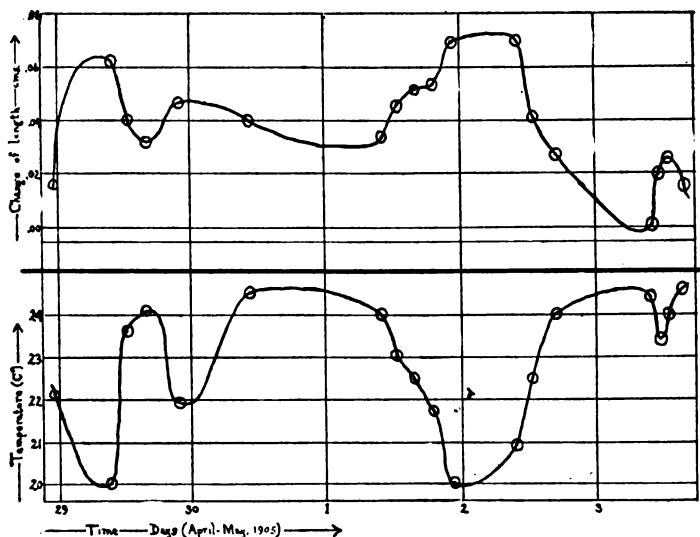


FIGURE 3.—Temperature and Length as Functions of Time.

4

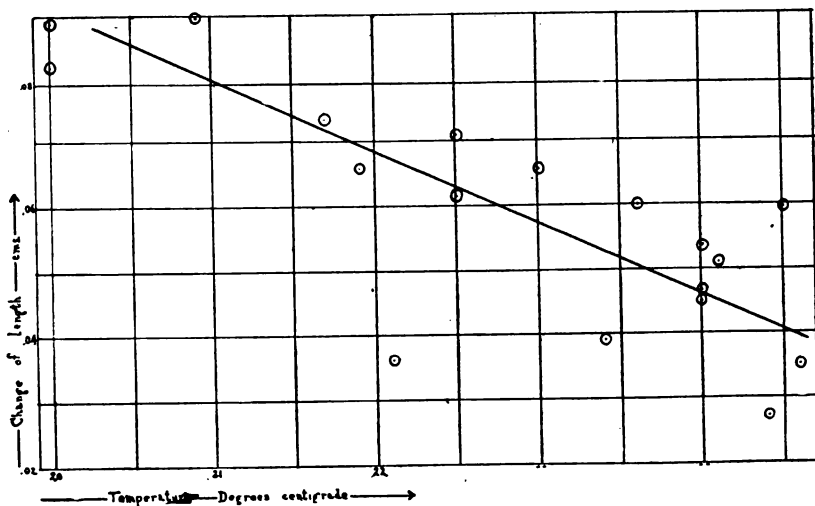


FIGURE 4.—Dependence of Length on Temperature.

but again the state of affairs is complicated by after-effects. These were simply neglected, however, and equations were set up for the determination of the coefficient of expansion, using eighteen observations; solving them by the method of least squares, the coefficient of linear expansion came out -0.000081 per degree centigrade. The observations used are shown graphically in figure 4. As the coefficient of expansion comes out *negative* and larger in absolute value than for most substances, the question arises whether the data obtained were not

5

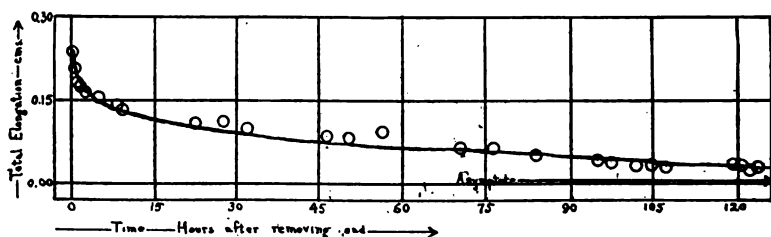


FIGURE 5.—Elastic After-effect upon removing 0.5 kg.

6

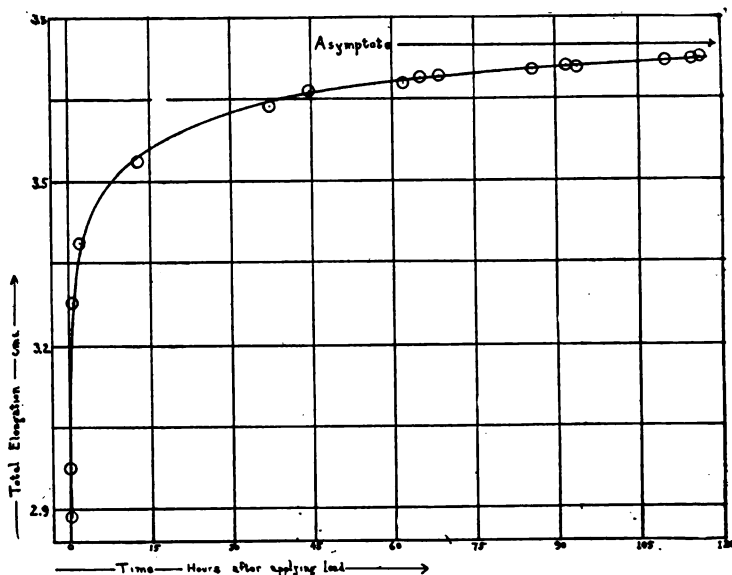
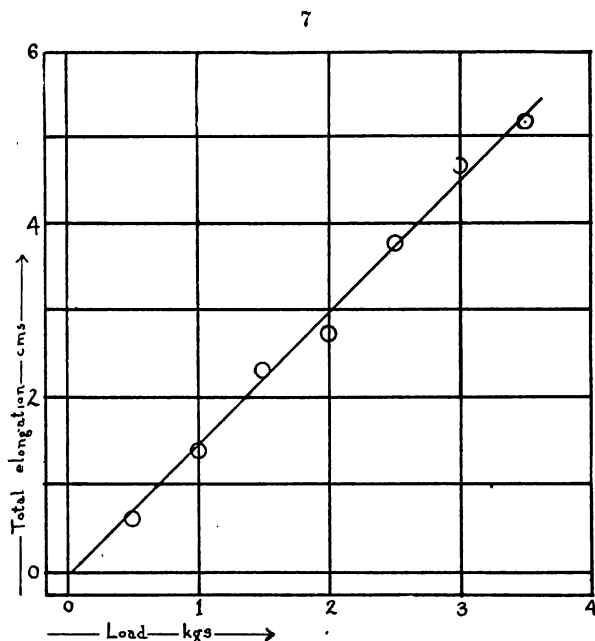


FIGURE 6.—Elastic After-effect upon applying 2.5 kgs.

influenced by humidity. In the enclosure containing the catgut, the *absolute* humidity was constant, but the *relative* humidity increased as the temperature fell; and it may be that under such conditions the material tends to absorb moisture and thus increase in length. It is possible, therefore, that in a perfectly dry atmosphere, the behavior of catgut under varying temperature might be quite different.

Elasticity.—To get at the true elastic properties of the material it would be necessary, after each change of load, to wait until the disappearance of the after-effect before determining the corresponding length of the string. In strictness,



an infinite time would be requisite for this; but practically the following procedure can be adopted, and was employed in these experiments: After each change of load, observations on the length of the string were made at intervals of a few hours for several days, and corrected for thermal expansion. From the data thus obtained, a curve was plotted with times for abscissas and lengths for ordinates; and from this curve the final length which the string tended to reach with disappearing after-effect, was estimated. Of course such an estimation involves considerable uncertainty and arbitrariness; but no other course seems available, as long as experiments must be

limited to finite time. Two of the curves obtained in this manner are exhibited in figures 5 and 6, together with their asymptotes as estimated. Such curves were taken after each change of load; but it is not thought to be of any interest here to submit more than two of them, or to present tables of the numerical data from which the curves are plotted.

The results obtained in this manner are summarized in the accompanying table. After any load had acted for a few days it was removed, and the string left unloaded a few days before the next load was applied. The individual readings were made to thousandths of centimeters; but the estimation of the length to which the string tended at infinite time was carried out only to hundredths. The first column of the table gives the loads, in kilograms, placed upon the hanger, which itself weighed about 0.5 kg.; the third column gives the total elongation after disappearance of the after-effect, estimated as explained above; the sixth column gives the after-effect, of change of strain from the first instant (practically about 60 seconds) after applying the load until final equilibrium is reached, expressed as percentage of the total final strain; the other columns require no explanation.

Violin E-string, 0.062^{cm} in diameter.

Load, in kgs.	Stress in kgs. per mm ² .	Total elonga- tion in cms.	Strain.	Young's modulus in kgs. per mm ² .	After- effect.	Time the load acted, in days.	Mean temper- ature. ° C.
0.5 { (applied) }	1.66	{ 0.59 }	0.0044	378	{ 30% }	5	24
{ (removed) }		{ 0.62 }			{ 33% }	5	24
1.0 (applied)	3.31	1.39	0.0101	328	44%	6	24
1.5 (removed)	4.97	2.26	0.0164	303	26%	5	25
2.0 { (applied) }	6.63	{ 2.70 }	0.0198	335	{ 22% }	4	28
{ (removed) }		{ 2.75 }			{ 29% }	7	29
2.5 { (applied) }	8.29	{ 3.78 }	0.0272	304	{ 22% }	5	31
{ (removed) }		{ 3.73 }			{ 29% }	4	28
3.0 (applied)	9.95	4.66	0.0338	294	20%	8	27
3.5 (applied)	11.60	5.17	0.0375	310	15%	6	28

*Young's Modulus.**—The mean value of Young's modulus from these experiments comes out 322 kgs. per mm², or 458,000

* The values of Young's modulus given in the above table are obtained by direct division of each stress by the corresponding strain. In strictness, Young's modulus should be determined from the slope of the stress-strain curve at the origin. But in the special case that the stress-strain curve is a straight line, the quotient of stress by strain for any point of the curve gives the same result as the slope at the origin. The data under discussion not being sufficiently regular to determine the true form of the stress-strain curve, it is taken as a straight line within the limits of the experiments; and this justifies the above method of determining Young's modulus.

lbs. per sq. in. If observations taken immediately after applying the loads had been used, instead of those after the disappearance of the after-effect, we would have about 400 kg. per mm² for Young's modulus; and this latter figure represents the elastic resistance of the material to a stress applied for a short time, as in longitudinal vibrations of the string.

Limit of Elasticity.—As is seen from the table, slight permanent set appears, though not with great certainty, after applying 2.5 kg (+0.5 kg. for the hanger). That makes the limit of elasticity about 8 kg. per mm², corresponding to a strain of 2.7 per cent.

Stress-strain Relation.—The results tabulated above are shown graphically in figure 7. It is clear from it that Hooke's law is *approximately* true; but the results obtained are too irregular to furnish ground for any definite statement as to deviations from Hooke's law.

Sewickley, Penn.

ART. XL.—*The Use of the Rotating Cathode for the Estimation of Cadmium taken as the Chloride*; by CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxl.]

IN a previous paper* the author has described the use of the rotating cathode for the estimation of cadmium taken as the sulphate. In the present paper a similar study has been made of the behavior of cadmium when taken in the form of the chloride. Some differences are to be expected, since it has been established with some certainty that cadmium chloride, when subjected to electrolysis, forms not only positive cadmium ions and negative chlorine ions, but also complex cadmium-chlorine negative ions; and, in addition, the chlorine, when set free, does not recombine with the water, to set free oxygen, but exists in the solution in its free state. That there are some very important differences a few qualitative experiments showed, so that the study of the estimation of cadmium when taken in the form of this salt was now undertaken.

A solution was made up to a convenient strength, and the standard determined by the mean of several closely agreeing determinations by the carbonate method, which the author had carefully tested and found to be perfectly reliable. This showed 0.1589 gram. of cadmium in 30^{cm}³ of the solution, or 0.0052966 gram. per cubic centimeter.

I. *In Solutions containing Sulphuric Acid.*

The procedure with cadmium chloride was the same as with the cadmium sulphate, and the results were very satisfactory. But emphasis is to be laid upon the dilution in this case especially, for it was found that from the more dilute solution it is almost impossible to drive the last traces of cadmium. A dilution of 45^{cm}³ was found to give the most satisfactory results. To this solution ten drops of sulphuric acid of 1:4 dilution were added before electrolysis. The following results were obtained under these conditions:

No.	Cd. gm.	Cur't = amp.	N. D. ₁₀₀ amp.	E.M.F. vts.	Time. min.	Cd. fd. gm.	Error. gm.
1.	0.1059	1.0-1.5	3.0-4.5	6.5-7.8	25	0.1054	-0.0005
1.	0.1059	2.0-3.0	6.0-9.0	7.8	15	0.1058	-0.0001

II. *In Solutions containing Acetates.*

The acetate method has proved one of the most satisfactory for the estimation of cadmium sulphate, but strangely enough,

* This Journal, xx, 268 (1905).

it was found to be absolutely unfitted for the estimation of cadmium when taken as the chloride. The deposited metal was always spongy, often non-adherent and unfitted for quantitative work. The sponginess was less marked when no potassium sulphate was present, but the metal was still poorly adherent and unweighable. The modifications tried are given for the sake of comparison in the following table. The current potential throughout was 7·8 volts, while the dilution, excepting in experiment No. 4, was 45^{cm}³. In No. 4 a dilution of 65^{cm}³ was tried, but it offered no apparent advantage.

No.	Cd. gram.	NaOC ₂ H ₃ O. gram.	K ₂ SO ₄ . gram.	Cur't = amp.	N. D. ₁₀₀ amp.	Time. min.	Notes.
1.	0·1324	1·5	0·5	1·5	4·5	13	very spongy
2.	0·1324	1·5	none	1·0	3·0	8	0·1314 gram. fd.
3.	0·1059	1·0	"	0·75	2·25	20	non-adherent.
4.	0·1059	1·5	0·5	1·5	4·5	—	{ spongy, non- adherent
5.	0·1059	1·5	none	1·0	3·0	—	{ 2 ^{cm} ³ formalin added, spongy
6.	0·1059	1·5	"	0·75	2·25	—	non-adht., cryst.
7.	0·1059	0·5	0·5	1·0	3·0	—	" "

III. In Solutions containing Cyanides.

The use of a cyanide solution gave results with the chloride of cadmium as satisfactory as were given when the sulphate of cadmium was taken. As in that case, care must be taken to avoid foaming of the solution. The best dilution seemed to be 65^{cm}³. The time required is a trifle longer than in the estimation of cadmium sulphate by this method. The following results were obtained:

No.	Cd. gram.	KCN.	NaOH.	Cur't = amp.	N. D. ₁₀₀ amp.	E.M.F. vts.	Time. min.	Cd. fd. gram.	Error. gram.
1.	0·1324	1·5	1·0	4	12	7·8	35	0·1322	—0·0002
2.	0·1324	1·5	1·0	4	12	7·8	40	0·1317	—0·0007

In experiment No. 2 there was much foaming, and a trace of cadmium remained in solution, the deposition being much retarded.

IV. In Solutions containing Pyrophosphates.

The different modifications of the pyrophosphate method gave results which were quite satisfactory, and in every respect comparable with the results obtained with this electrolyte in the estimation of cadmium sulphate. As was the case with that salt, the use of ammonium hydroxide to dissolve the precipitate gave the most satisfactory results; while after that, sulphuric acid seemed to be the most suitable

solvent. The deposits obtained from solutions to which were added free phosphoric acid showed a slight tendency toward sponginess. When hydrochloric acid was added, the deposits were good but deposition was slow. The total volume in each case was 45^{cm}³; the amount of sodium pyrophosphate used was 9.5 grm.; while the current potential was 7.8 volts.

The following results were obtained:

No.	Cd. grm.	Solvent.	Cur't = amp.	N. D. ₁₀₀ . amp.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0.1324	NH ₄ OH, conc., 1 ^{cm} ³.	0.5	1.5	15	0.1327	+0.0003
2.	0.1324	H ₂ SO ₄ , (1.4), 12 dps.	0.75	2.25	35	0.1328	+0.0004
3.	0.1342	H ₃ PO ₄ , (sp. gr. 1.7), 15 dps.	0.75-1.0	2.25-3.0	30	0.1331	+0.0007
4.	0.1324	HCl, 1:4, 15 dps.	0.7-0.5	2.1-1.5	45	0.1319	-0.0005

V. In Solutions containing Phosphates.

With cadmium chloride, hydrogen disodic phosphate must be used with even more care than with cadmium sulphate, if deposits which are even slightly satisfactory are to be obtained; and even when used with caution, the tendency to form spongy deposits is so persistent that this method is not to be recommended where other methods are available. The following are the solutions tried, the concentration being 45^{cm}³ throughout:

No.	Cd. grm.	HNa ₂ PO ₄ . grm.	H ₃ PO ₄ . (sp. gr. 1.7)	Cur't = amp.	N. D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error grm.
1.	0.1059	0.25	5 ^{cm} ³	2.0-3.0	6.0-9.0	7.8	15	0.1082	+0.0023
2.	0.1324	0.25	2.5 ^{cm} ³	2.0-3.0	6.0-9.0	7.8	13	0.1344	+0.0020
3.	0.1324	0.20	10 dps	1.0	3.0	7.8	15	0.1330	+0.0006
4.	0.1324	0.20	6 dps	0.25	0.75	7.8	35	0.1310	-0.0014

Numbers 1 and 2 gave spongy deposits; number 4 showed no color upon testing the solution at the end of the operation with hydrogen sulphide, but this test does not seem to be very sensitive in this solution. Number 3 seems to represent the best conditions.

VI. In Solutions containing Oxalates.

Several qualitative tests, using conditions identical with those giving the least unsatisfactory deposits with cadmium sulphate, were tried upon the cadmium chloride, with like unsatisfactory results, so that the work upon the oxalate method was not pursued further.

VII. In Solutions containing Urea, etc.

A few qualitative tests seemed to indicate that solutions containing urea, formaldehyde or acetaldehyde would furnish very satisfactory media for the estimation of cadmium, taken in the form of the chloride, but further experimentation proved these appearances to be deceptive. Under these conditions,

the cadmium is deposited much more quickly from a solution of its chloride than of the sulphate, and the deposit in the earlier part of the precipitation appears to be very satisfactory. But the chlorine set free apparently has some action upon the organic compound present to produce substances detrimental to the process. With care, however, satisfactory results may be obtained, as may be seen from a study of the following tables:

SERIES A.—UREA.

No.	Cd. grm.	Urea. grm.	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Tol. vol. cm ³ .	Cd. fd. grm.	Error. grm.	Notes.
1.	0.1324	3	1.0	3.0	12	20	60	0.1312	-0.0012	{ spongy, not all out
2.	0.1324	2	1.0	3.0	12	30	60	0.1336	+0.0012	{ spongy, not all out
3.	0.1324	3	1.0	3.0	7.8	15	55	0.1342	+0.0018	{ very spongy, all out
4.	0.1324	2	0.25	0.75	7.8	25	60	0.1324	±0.0000	all out
5.	0.1324	2	0.5	1.5	12	20	60	0.1333	+0.0009	{ slt. spy. all out
6.	0.1324	1	1.0	3.0	12	20	60	0.1370	+0.0046	{ very spongy
7.	0.1324	1.5	0.25-0.5	0.75-1.5	7.8	30	60	0.1328	+0.0004	good
8.	0.1324	1.5	0.25-0.5	0.75-1.5	7.8	30	60	0.1329	+0.0005	fair

The amount of urea present, therefore, should be between 1.5 gm. and 2 grms., and the current potential should not exceed 8 volts, instead of the 12 volts permissible when cadmium sulphate was used. The test with hydrogen sulphide does not seem to be very delicate in this solution, so that at least 30 minutes should be allowed for each determination. Some writers recommend the testing of the end-point in similar cases by raising the level of the liquid upon the cathode, but this was not proved of much value in this work, as the amount of metal deposited upon the fresh cathode surface from the solutions near the end of the process is imperceptible.

A solution to which formaldehyde was added gave the following results:

SERIES B.—FORMALDEHYDE (FORMALIN).

No.	Cd. grm.	Form. cm ³ .	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Tol. vol. cm ³ .	Cd. fd. grm.	Error. grm.	Notes.
1.	0.1324	3.0	0.25-1.5	0.75-4.5	7.8	20	45	0.1333	+0.0009	fair
2.	0.1324	2.0	0.50-2.0	1.50-6.0	11.8	15	45	0.1330	+0.0006	slt. spgy
3.	0.1324	1.5	0.75	2.25	7.8	30	60	0.1324	±0.0000	compact
4.	0.1324	1.5	1.0	3.0	7.8	35	60	0.1325	+0.0001	"

It will be seen from these results that it is better to use a somewhat smaller quantity of formaldehyde than was used with the cadmium sulphate; the current potential should not exceed 8 volts; while the solution should be rather dilute (60cm^3).

These cautions are of even greater importance when acetaldehyde is used, if satisfactory results are to be obtained, as the following results show :

SERIES C.—ACETALDEHYDE (95%).

No.	Cd. grm.	Aldehyd. (95%) cm^3 .	Cur't = amp.	N.D. ₁₀₀ . amp.	E.M.F. vts.	Time. min.	Tot. vol. cm^3 .	Cd. fd. grm.	Error. grm.	Notes.
1.	0.1324	2.0	0.2-0.7	0.6-2.1	7.8	30	60	0.1311	-0.0013	{ not all out
2.	0.1324	1.5	0.2-0.75	0.6-2.25	7.8	30	60	0.1346	+0.0022	
3.	0.1324	0.5	0.2-1.0	0.6-3.0	7.8	65	60	0.1307	-0.0017	{ spongy, not all out
4.	0.1324	1.0	0.1-0.75	0.3-2.25	8.0	35	60	0.1328	-0.0001	

VIII. *In Solutions containing Formates and Tartrates.*

Like cadmium sulphate, so also cadmium chloride gave negative results when solutions containing in addition potassium formate in the presence of formic acid were subjected to electrolysis. Moreover, when no formate was added, but formic acid alone, the results were still unsatisfactory. To solutions containing 0.1324 grm. of cadmium in the form of the chloride was added 1.5cm^3 of formic acid, the whole diluted to 50cm^3 , and electrolysis conducted under potentials of 7.5 and 11.8 volts. In each case the precipitate was spongy and non-adherent, while the solution persistently held traces of cadmium, even after subjecting to the current nearly two hours.

Solutions containing tartaric acid behaved in a similar manner. In the presence of 3 grm. of tartaric acid, under current tensions of 8 and 12 volts, the precipitated metal peeled from the cathode during revolution, the deposit was spongy, and deposition seemed to be complete at no point of the operation.

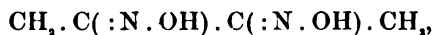
SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Formation of Ozone by Ultra-violet Light.*—FISCHER and BRAEMER, by employing a mercury-vapor lamp with quartz walls, have studied the effect of ultra-violet light upon oxygen. They have found that ozonization takes place if the temperature is not too high, for above 270° ozone is decomposed more rapidly than it is formed. Thorough cooling of the oxygen by means of a water-jacket increased the yield of ozone, while a greater intensity of the light of the lamp also increased the yield to a certain limit and then decreased it, probably on account of the effect of greater heating. Upon doubling the speed of the oxygen through the apparatus the total amount of ozone formed was nearly doubled, but the percentage of ozone formed was somewhat diminished. The authors believe that their experiments show the correctness of Warburg's view, that the formation of ozone by the silent electric discharge is due to the ultra-violet light thus formed. A short time ago one of the authors found that their lamp could produce in a few hours the violet coloration of glass containing manganese, which is effected by sunlight in high mountainous regions in months or years, and in our low regions only after longer periods, because the ultra-violet part of its spectrum is strongly absorbed by the earth's atmosphere. By this absorption of ultra-violet sunlight by our atmosphere ozone results in the upper layers of air, and when it sinks to lower regions it is decomposed by oxidizable substances.—*Berichte*, xxxviii, 2633.

H. J. W.

2. *A New Reagent for Nickel.*—Heretofore there has been no characteristic and delicate reaction for nickel, particularly in the presence of considerable amounts of cobalt. The most delicate of the known tests is probably the brown color produced by alkali thiocarbonates, but this is interfered with by the presence of cobalt. TSCHUGAEFF has recently found that α -dimethylglyoxime,



is an extraordinarily delicate and characteristic reagent for the metal under consideration. To make the test, the solution is first freed from any excess of acid by the addition of alkali (preferably an excess of ammonia or sodium acetate solution), then some powdered dioxime is added and the solution is heated to boiling for a short time. If the solution is not exceedingly dilute, a scarlet precipitate is produced at once having the composition $\text{NiD} \cdot \text{DH}_2$, where DH_2 represents dioxime. When very small amounts of nickel are present a yellowish liquid is obtained, from which, after cooling, the red precipitate is deposited after a few minutes, whereby the excess of dioxime which separates at

the same time is colored distinctly pink. The delicacy of this reaction is so great that it is very distinct in solutions containing only one part of nickel to 400,000 parts of water. The reaction is not at all masked by the presence of ten times as much cobalt as nickel, but since cobalt salts also react with the dimethylglyoxime with the formation of a brown compound, it is expedient to modify the process when much cobalt is present by adding a very large excess of ammonia to the liquid, then shaking repeatedly in order to oxidize the cobalt to complex cobaltic-ammonia compounds, and then proceeding as before. In this case, with not too minute amounts of nickel, the reaction appears at once, when the liquid is boiled, by the formation of a scarlet froth which rises upon the walls of the test-tube, but generally it is necessary to filter the cooled liquid and to wash the residue with water in order to detect its pink color. The author gives a method for preparing the new reagent, and states that it may be obtained commercially from Kahlbaum.—*Berichte*, xxxviii, 2520.

H. L. W.

3. *The Electrolytic Dissociation Theory with some of its Applications*; by HENRY P. TALBOT and ARTHUR A. BLANCHARD, 8vo, pp. 84. New York, 1905 (The Macmillan Co.).—This is an elementary treatise for the use of students of chemistry. It deals with the fundamental topics of physical chemistry in a very clear and simple manner, and it is undoubtedly a valuable text-book for students who are not far enough advanced to take up the subject more elaborately. The six chapters of the book have the following titles: "Evidences of Electrolytic Dissociation afforded by a Study of the Properties of Solutions," "The Law of Mass Action and the Chemical Behavior of Electrolytes," "Electrolytic Solution Pressure," "Oxidation and Reduction," "The More Common Ions and their Characteristics," "Experiments."

H. L. W.

4. *Soils and Fertilizers*; by HARRY SCHNEIDER, 8vo, pp. 294. Easton, Pa., 1905 (The Chemical Publishing Co.).—This book gives in condensed form the principles of chemistry which have a bearing upon the conservation of soil fertility and the economic use of fertilizers. While it is intended particularly as a text-book for students in agricultural colleges, and includes a course of laboratory experiments for such students, it presents the subject in such a practical manner that it should find extensive use among farmers. The present second edition has been entirely rewritten, and has received the addition of new material.

H. L. W.

5. *Engineering Chemistry*; by THOMAS B. STILLMAN, Third Edition, 8vo, pp. 597. Easton, Pa., 1905 (The Chemical Publishing Co.).—The third edition of this well-known work on technical analysis contains much new matter, especially in regard to asphalts, lubricating-oils, Portland cement, and the technology of the products of the blast-furnace. In its present form the book will be more useful than ever to those who are interested in commercial chemistry.

H. L. W.

6. *A Text-Book of Chemical Arithmetic*; by H. L. WELLS, 12mo, pp. 169, 1905. New York (John Wiley & Sons).—Every instructor in chemistry knows how difficult it is to induce students to use their reasoning powers in solving simple problems. The tendency is always to use a formula or a factor without knowing or caring what these may mean. This text-book is designed to teach chemical arithmetic, but on a basis of reason rather than rules. Part I on approximate numbers deals with calculations from measurements involving errors of observation. The abbreviated methods of multiplication and division are also given. The rest of the book deals with chemical calculations relating to weights, to gases, and to volumetric analysis. Throughout the book, a large number of very practical problems is given. A student who has once solved these problems intelligently should certainly have no further trouble with chemical calculations. In an appendix, several convenient tables are given, including a table of logarithms.

H. W. F.

7. *A Text Book of Physiological Chemistry for Students of Medicine*; by JOHN H. LONG, Professor of Chemistry in Northwestern University Medical School, Chicago. Pp. viii + 424. Illustrated. Philadelphia, 1905 (P. Blakiston's Son).—In this volume are presented in a clear and simple form the necessary facts and principles underlying the science of physiological chemistry, written for use by students in medical schools, but few references are made to the literature. Besides the general topics usually treated of in a book of this character there is given an outline of the chemical phases of recent theories of immunity together with explanations of the application of the methods of cryoscopy and electrical conductivity and other physical processes in the field of chemistry related to medicine. The book is well adapted to the purpose for which it was written and should be well received.

F. P. UNDERHILL.

8. *Formation of Helium from the Radium Emanation*.—In answer to many inquiries called forth by an article on this subject, published in the *Berichte d. naturf. Ges. Freiburg i. Br.* xvi, p. 222, 1904, F. HIMSTEDT and G. MEYER relate further experiments upon this subject. They have repeated their work with RaBr_2 and also with BaBr_2 by the same method. Using a much greater amount of material, they never found a trace of a helium line. They still possess, however, three tubes which show with the greatest ease the helium spectrum, which could not have come from the air of the room or from any source but the emanation.

In order to determine whether any occlusion phenomenon similar to the occlusion of hydrogen by palladium was concerned in the appearance of helium, they made the following experiments:

Palladium foil filled with hydrogen was placed in a quartz tube connected to a vacuum pump, and in the process of exhaustion was heated to a red heat and was flushed out with CO , until every trace of the hydrogen spectrum disappeared. After three

days, on heating, the hydrogen spectrum reappeared. After eight days, on repetition of the heating, the hydrogen lines again appeared. Further examination was prevented by the breaking of the tube.

The following experiment with cleveite led to a totally different result. In a combustion tube 0.3 g. of cleveite with SO_4KH was strongly heated and the tube flushed with hydrogen until no helium lines could be seen. The tube was then exhausted as far as possible. After three days, perhaps, there was a trace of the helium spectrum; but repeated heating and pumping disclosed in fourteen days no trace of helium. This experiment was repeated without SO_4KH with the same result.

In marked contrast to this experiment was the following: About 40 mg. RaBr_2 were so strongly heated in a highly exhausted quartz tube that the substance resublimed in a cooled end of the tube. The tube was flushed with hydrogen and exhausted, and on the following day the substance was again resublimed; no trace of the helium spectrum was seen. In six weeks, however, the helium spectrum could be readily produced in the tube. These experiments appear to the author to dispose of the theory of occlusion.

They point out that there may be a possibility of the formation of a helid. Instead of pure RaBr_2 , we may be dealing with a mixture of this substance with a small quantity of a hypothetical helid. However this may be, they conclude that there is no doubt of a connection between the radium emanation and helium. — *Ann. der Physik*, No. 10, 1905, pp. 905–1008. J. T.

9. *Blondlot's "Emission pesante."*—M. R. BLONDLOT published in the *Comptes Rendus* issues of 1904 two papers on a phenomenon analogous to the so-called N-rays, to which he gave the name "emission pesante." A preparation of calcium sulphide becomes more luminescent under the influence of this emission. Blondlot states that he has not only observed this increase in luminescence, but also an effect of the magnetic field on the emission. Rudolf F. Pozdena has made an exhaustive examination of the effects claimed by Blondlot and cannot find any evidence of the new emission if the observer does not conduct the experiments himself. The phenomenon is a subjective one and may arise in the anatomy of the retina of the eye by a species of autosuggestion leading to a "Will to believe." — *Ann. der Physik*, No. 6, 1905, pp. 104–131. J. T.

10. *Diffusion of Nascent Hydrogen through Iron.*—A. WINKLEMAN has conducted a long series of experiments upon this subject with the following conclusions:

The nascent hydrogen being formed on the outside of a hollow iron cylinder which was closed at the bottom and connected at the other end with an air-pump, the iron cylinder serving as a cathode in a suitable electrolytic cell, it was found:

(1) The quantity of gas diffusing from the outside to the inside of the cylinder was independent of the pressure inside the cylinder.

der over a range of 0 to 89^{cm} of mercury. The quantity, moreover, was not altered if the exterior pressure on the iron cylinder was varied from one to a half atmosphere. The pressure, therefore, under which the gas is driven through the iron is of a different nature from that which one might suppose and has an under limit of 58 atmospheres.

(2) The diffusion with constant current strength increases notably with the temperature; and if one puts the diffusion proportional to a power of the absolute temperature, this power is at least equal to 5.

(3) The diffusion increases at constant temperature with increasing current strength but not in a proportionate manner.

(4) From 1 and 3 one can understand the observations of Nernst which show that the pressure of the ions formed electrolytically can be very great and that this pressure depends upon the potential difference under which the electrolysis occurs. In view of this great pressure which drives the ions through the metal, one can understand the no effect on one to a half atmosphere mentioned in 1; also one does not wonder at the results of Bellanti and Lussana, who found that diffusion occurred even against a pressure of 20 atmospheres.

(5) At constant temperature and similar conditions of solutions and electrodes the quantity of diffusion was nearly proportional to the potential difference.—*Ann. der Physik*, No. 9, 1905, pp. 589–626.

J. T.

11. *Landolt-Börnstein Physikalisch-chemische Tabellen*. Dritte umgearbeitete und vermehrte Auflage, herausgegeben von Dr. RICHARD BÖRNSTEIN und Dr. WILHELM MEYERHOFFER. 861 pp. Berlin, 1905 (Julius Springer).—The first edition of this very important work was published in 1883 and the second in 1894. The decade that has passed since the latter date has seen a very high degree of activity in physical research and a corresponding increase in the amount of physical data. In the working over and arrangement of this large amount of material, the editors have had the support of upwards of forty associates, chiefly in Germany; the work has been carried through with the support of the Prussian Academy of Sciences. The volume opens with the international atomic weights of 1903 calculated with oxygen = 16. Then follow tables of latitude and longitude of important places and then the tables of physical data relating to volume, density, elasticity, tension, etc.; then those pertaining to heat, light, elasticity, magnetism and sound. The name of the worker who has elaborated each series of tables is given at the bottom of each page and following each subject are the references to the literature giving fully the authorities quoted. The comprehensive scope, thoroughness and accuracy of this great work give it a unique place in physical literature and make it essential to every laboratory.

II. GEOLOGY AND MINERALOGY.

1. *United States Geological Survey*: CHARLES D. WALCOTT, Director.—Recent publications of the U. S. Geological Survey are included in the following list. Notices are for the most part deferred till a later number.

FOLIOS: No. 122.—Tahlequah Quadrangle, Indian Territory—Arkansas; by JOSEPH A. TAFF.

No. 123.—Elders Ridge Quadrangle, Pennsylvania; by RALPH W. STONE.

No. 124.—Mount Mitchell Quadrangle, North Carolina—Tennessee; by ARTHUR KEITH.

No. 125.—Rural Valley Quadrangle, Pennsylvania; by CHARLES BUTTS.

MONOGRAPH, No. XLVIII.—Status of the Mesozoic Floras of the United States. Second Paper; by LESTER F. WARD, with the collaboration of William M. Fontaine, Arthur Bibbins and G. R. Wieland. Part I, Text, pp. 616. Part II, plates i-cxix.

PROFESSIONAL PAPERS: No. 34.—The Delavan Lobe of the Lake Michigan Glacier of the Wisconsin Stage of Glaciation and Associated Phenomena; by WILLIAM C. ALDEN. Pp. 106, with 15 plates. See p. 409.

No. 36.—The Lead, Zinc and Fluorspar Deposits of Western Kentucky; by E. O. ULRICH and W. S. TANGIER-SMITH. Part I, Geology and General Relations by E. O. Ulrich. Pp. 1-105, plates i-vii. Part II, Ore Deposits and Mines by W. S. Tangier-Smith. Pp. 107-218, plates viii-xv, 31 text-figures.

No. 38.—Economic Geology of the Brigham Mining District, Utah; by JOHN MASON BOUTWELL. With a Section on Areal Geology by ARTHUR KEITH and an Introduction on General Geology by SAMUEL FRANKLIN EMMONS. Pp. 413, 49 plates, 10 figures.

BULLETINS—No. 208.—Descriptive Geology of Nevada south of the Fortieth Parallel and Adjacent Portions of California; by JOSIAH EDWARD SPURR. Second edition. Pp. 229, 8 plates. Map in pocket.

No. 235.—A Geological Reconnaissance across the Cascade Range near the Forty-ninth parallel; by GEORGE OTIS SMITH and FRANK C. CALKINS. Pp. 103, 4 plates. It is found that "the Cascade Mountains near the forty-ninth parallel are composed in greater part of igneous rocks that belong mainly to great batholithic masses of rather acidic composition quite comparable (in volume) with the immense intrusions of the Sierra Nevada."

No. 237.—Petrography and Geology of the Igneous Rocks of Highwood Mountains, Montana; by LOUIS VALENTINE PIRSSON. Pp. 208, 7 plates, 8 figures.

No. 245.—Results of Primary Triangulation and Primary Traverse, fiscal year 1903-04; by SAMUEL S. GANNETT. Pp. 328 with map.

No. 247.—The Fairhaven Gold Placers, Seward Peninsula, Alaska ; by FRED H. MOFFIT. Pp. 85, 14 plates, 2 figures.

No. 248.—A Gazetteer of Indian Territory ; by HENRY GANNETT. Pp. 70.

No. 251.—The Gold Placers of the Fortymile, Birch creek and Fairbanks Region, Alaska ; by LOUIS M. PRINDLE. Pp. 89, 16 plates.

No. 253.—Comparison of a Wet and Crucible-fire methods for the Assay of Gold Telluride Ores, with notes on the errors occurring in the operations of fire assay and parting ; by W. F. HILLEBRAND and E. T. ALLEN. Pp. 30.

No. 254.—Report of Progress in the Geological Resurvey of the Cripple Creek District, Colorado ; by WALDEMAR LINDGREN and FREDERICK LESLIE RANSOME. Pp. 34.—Besides the details of more purely economic importance it is noted that in the deeper workings much annoyance and even serious interference with work has been experienced from mine gases, often in spite of vigorous measures for ventilation. The analyses showed the gas to be a mixture of nitrogen with about 20 per cent carbon dioxide and a small amount of oxygen. The authors believe that it represents the last exhalations from the throat of the extinct Cripple Creek volcano.

No. 256.—Mineral Resources of the Elders Ridge Quadrangle, Pennsylvania ; by RALPH W. STONE. 86 pp., 12 plates, 4 figures.

No. 257.—Geology and Paleontology of the Judith River Beds ; by T. W. STANTON and J. B. HATCHER ; with a chapter on the Fossil Plants ; by F. H. KNOWLTON. Pp. 174, 19 plates.

No. 262.—Contributions to Mineralogy from the U. S. Geological Survey ; by F. W. CLARKE, W. F. HILLEBRAND and others. Pp. 147, 12 text-figures.

No. 263.—Methods and Costs of Gravel and Placer Mining in Alaska ; by CHESTER WELLS PURINGTON. Pp. 273, 42 plates, 49 figures.

No. 266.—Paleontology of the Malone Jurassic Formation of Texas ; by F. W. CRAGIN ; with stratigraphic notes on Malone Mountain and the surrounding region near Sierra Blanca, Texas ; by T. W. STANTON. Pp. 172, 29 plates.

No. 267.—The Copper Deposits of Missouri ; by H. F. BAIN and E. O. ULRICH. Pp. 52.

No. 271.—Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy for the year 1904 ; by FRED BOUGHTON WEEKS. Pp. 218.

WATER SUPPLY AND IRRIGATION PAPERS.—Nos. 97, 98, 99, 100, 103, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 124, 125, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 141, 143, 144, 146, 149.

2. *Osteology of Baptanodon* (Marsh) ; by C. W. GILMORE. Memoirs of the Carnegie Museum, Vol. II, No. 2, August, 1905.

—Mr. Gilmore's excellent paper gives us for the first time a satisfactory discussion of the osteological structure of the Jurassic

Ichthyosauria of America. Notes by Marsh and Knight have acquainted us with the essential characters of the paddles, but little information concerning the remainder of the skeleton has been published, and investigators working on related groups have had no satisfactory basis for comparison with these important forms. The specimens studied by Mr. Gilmore include practically all of the known *Baptanodon* material. The figures presented represent the complete structure of the skull in all its aspects, the pectoral girdle, the anterior limb, and the anterior portion of the vertebral column. The posterior limb is not certainly known.

The characters of the dentition of *Baptanodon*, for the original discovery of which we are indebted to Mr. Gilmore, have been summed up in the statement that: "*Baptanodon* was well provided with comparatively small, somewhat slender but functional teeth that extended along the full length of the jaw; the most anterior ones being much reduced." In addition to the characters of the dentition, Mr. Gilmore notes specializations in the reduction of the cervical intercentra to a simple free element in *B. marshi*, the median fusion of the clavicles, and the presence of a sixth digit in the anterior limb.

In the comparison of *Baptanodon* with the European *Ophthalmosaurus*, the two are shown to be remarkably similar. Distinguishing characters are found in the presence in *Baptanodon* of a sixth digit in the anterior limb, the uniform biconcave cupping of the anterior cervical centra, and the fusion of the clavicles. The two types are, however, very close together, as similar as one could reasonably expect to find species so widely separated geographically.

In the light of what is actually known, the relation of *Baptanodon* to the later Triassic forms of America seems still far from close. *Shastisaurus*, the youngest known Triassic genus, is at least in limb structure highly specialized along a line almost diametrically opposite that taken by *Baptanodon*. Unless a closer connection with the late Triassic forms of this continent can be discovered, we must continue to look upon *Baptanodon* as probably a Jurassic immigrant from the old world. The close relationship to the European *Ophthalmosaurus* is additional evidence in favor of the suggestion that *Baptanodon* was a Jurassic importation. In this connection it is interesting to note that Frass* has recently described a vertebra which he believes to represent the genus *Ophthalmosaurus*, from the Jurassic of North-east Greenland.

JOHN C. MERRIAM.

3. *Cambrian Faunas of India*; by CHARLES D. WALCOTT. Proc. U. S. National Museum, xxxix, 1905, pp. 1-106.—This paper is the result of a preliminary study of the Cambrian material collected by Mr. Blackwelder, as a member of the Carnegie Institution of Washington Expedition to China, under the leadership of Mr. Bailey Willis. Previous to this expedition, Kayser,

* E. Frass, Meddelelser om Grönland, xxix, p. 283.

Dames, and Bergeron had described 21 species, which are now increased by Walcott to 172 forms, of which 118 are trilobites. "The large fauna discovered in the reconnaissance made by Messrs. Willis and Blackwelder is an indication of the richness of the Cambrian faunas of eastern Asia, and of the great results that may be expected when systematic, thorough exploration and collecting are undertaken."

Almost the entire Cambrian seems to be represented here, and rests on the Tai Shan complex. The Lower Cambrian in the Man To formation has 12 species, and as the trilobite *Redlichia* is the diagnostic fossil, seemingly being a direct descendant of *Olenellus*, we are led to infer that the lower portion of the Lower Cambrian, as known in America, may be absent in China. The Middle Cambrian in the Chang Hsia formation is the richest in fossils. Another and higher member of this division is the Ku San shale, with a small fauna; followed by the Upper Cambrian in the Chao Mi Tien limestone, having another considerable faunal development.

"The fauna of the Ku San shale includes species of *Damesella*, *Dorpyge*, and genera that are typical of the Middle Cambrian fauna, while the fauna of the Chao Mi Tien limestone . . . is more nearly related to that of the Upper Cambrian of North America and northwestern Europe."

Walcott's lists clearly indicate that the Middle Cambrian of China is directly connected with that of America, a fact long ago noted by Dames, and recently more decidedly by Frech. The Upper Cambrian also has the American impress, while the Lower Cambrian is Asiatic in character.

The oldest known cephalopod is described here as *Cyrtoceras cambria*. The structure, as described, is that of *Cyrtoceras*, but one would rather have looked for *Piloceras* or *Endoceras*-like forms in the Cambrian. Brachiopods, gastropods, and especially trilobites make up the faunas, while not a single bivalve is here recorded. Of new genera—all trilobites—there are *Dorpygella*, *Damesella*, *Anomocarella*, *Pagodia*, and *Shantungia*. c. s.

4. *The Cambrian Fauna of India*; by CHARLES D. WALCOTT. Proc. Washington Acad. Sci., vii, 1905, pp. 251-256. — The writer here reviews the small Cambrian fauna of India first described by Waagen; this has also been referred to the Silurian and Carboniferous. Walcott concludes: "In the absence of any fossils clearly indicating the *Olenellus* fauna I think it unwise at present to assume any other age for the fossiliferous Cambrian beds than Middle Cambrian." c. s.

5. *Catalogue of the Type Specimens of Fossil Invertebrates in the Department of Geology, U. S. National Museum*; by CHARLES SCHUCHERT, assisted by W. H. DALL, T. W. STANTON, and R. S. BASSLER. Bull. U. S. National Museum, No. 53, Part I, 1905, pp. i-v, 1-704. — This is an alphabetic catalogue of the type and illustrated fossil invertebrates in this museum, previous to 1905. It records 11,490 specimens of 6,100 species. Within

the past few years, three similar catalogues have been published. The first one, by the American Museum of Natural History, New York City; the second, by the New York State Museum, Albany, New York, and now the one cited above. The last, however, records the largest number of species, and is an indication of the great amount of paleontological work done at Washington.

6. *Graptolites of New York. Part I, Graptolites of the Lower Beds*; by R. RUEDEMANN. N. Y. State Mus., Mem. 7, 1904 (distributed March 1905), pp. 457-803, pls. 1-17.—This very valuable monograph had its origin in stratigraphic work by the author, in the slate belt of eastern New York. The book is of the greatest importance, not only to paleontologists and paleogeographers, but as well to the stratigrapher of the older Paleozoic formations. In fact, the work is so valuable that no review could bring out its many excellent points, unless it were of great length, for which space is not at our disposal. In this monograph are treated the late Cambrian and early Ordovician graptolites of America, the species and genera not only being described and illustrated, but also their structure, morphology, reproduction, development, mode of existence, phylogeny, and systematic position, as well as the bearing of these organisms on the stratigraphy and paleogeography of Ordovician time. C. S.

7. *Mesozoic Plants from Korea*; by H. YABE. Jour. College Sci., Imperial University, Tokyo, Japan, 1905, pp. 1-59, pls. i-iv.—Here are described 21 species, 3 of which are new. Filices are the most prevalent, being represented by 11 species.

"It is quite evident that the flora is Jurassic, for neither typically Rhaetic or Cretaceous forms are found in it."

"On the whole, so far as evidence goes, the writer has little hesitation in announcing the contemporaneity of the Naktong flora of Korea with that of the Japanese Tetori series [about Malm and Dogger], the affinity of the former to those of the corresponding age in Siberia, China, India and California being apparently more distant." C. S.

8. *Palaeontologia Universalis*.—Early in September of the present year, there appeared the first fascicle of the second series of this important publication. Ninety-four species are now re-described and refigured and brought up to date. C. S.

9. *Ninth Annual Report of the Geological Commission, Dept. of Agriculture, Cape of Good Hope, for 1904*. Pp. 181 with numerous maps and figures. Cape Town, 1905.—This report contains the description of the detailed survey of several districts in the Colony of the Cape of Good Hope; thus adding valuable detail to the general works on South African geology which have recently appeared. J. B.

10. *Rock Cleavage*; by CHARLES KENNETH LEITH. Bulletin 239, U. S. Geol. Surv., 1905, pp. 216. 27 pls.—As noted by Dr. C. W. Hayes in the letter of transmittal, "The paper embodies the results of a very careful and laborious investigation of facts concerning rock cleavage and a discussion of their theoretical

significance. Its publication will place the subject of rock cleavage in a much more satisfactory shape and be of material assistance to all structural geologists." The writer divides secondary or induced cleavage into *flow-cleavage* and *fracture-cleavage*. The first is considered as depending upon a parallel arrangement of mineral particles and is shown to be developed by rock flowage, the cleavage, as held by Van Hise and Hoskins, developing at any instant normal to the greatest pressure, but the final direction of cleavage may be inclined to the direction of greatest pressure which has produced the deformation. Fracture-cleavage on the other hand is considered as not dependent upon a parallel arrangement of mineral constituents and as arising in a plane of shear in the outer zones of the earth's crust. The writer follows the inductive method of studying the facts in the field and laboratory and pointing out their significance. J. B.

11. *Experiments on Schistosity and Slaty Cleavage*; by GEORGE F. BECKER. Bulletin 241, U. S. Geol. Surv., 1904, pp. 34, 7 pls.—This bulletin embraces the results of valuable experiments upon clay and ceresin in a "scission engine" of the author's invention in order to test disputed theories of cleavage. The results show, according to Dr. Becker, that in these cases the cleavage arose on planes of shear and not in the planes subjected to greatest pressure. This is in conformity with the author's conclusions published ten years previously and these are regarded by him as establishing his contention that all cleavage is to be regarded as arising in planes of shear. As noted in the previous review, Professor Leith grants the occurrence of this form of cleavage, but regards it as only of partial application to the natural phenomena and distinct from the more common flow-cleavage. Leith also differs from Dr. Becker in the interpretation of the experiments, regarding the results as due to flow-cleavage. J. B.

12. *Die Alpen im Eiszeitalter*; von Dr. ALBRECHT PENCK, Professor an der Universität Wien und Dr. EDUARD BRÜCKNER, Professor an der Universität Bern. Part 6, pp. 545-656, 1904; Part 7, pp. 657-784. Leipzig, 1905.—These two parts continue the discussion of the Alps in the Glacial Period, and it is expected that the series will be completed upon the issuance of one more part. The volumes are well illustrated by profiles, maps, and photographs, and the names of the authors are a guarantee as to the quality of the work.

The subjects discussed in part 6 include the glacial history of the Reuss, Aar and Rhone valleys, the physiographic features and the nature of the interglacial plant remains. Part 7 deals chiefly with the French and southern Alps and discusses the paleolithic finds and their relation to the glacial and interglacial times. This work is of the utmost interest to anthropologists as well as to glacialists and physiographers and will rank for many years as a standard contribution to the Quaternary history of Central Europe. J. B.

13. *Structural and Field Geology*; by JAMES GEIKIE. Pp. xx + 435, 56 page plates, 142 text illustrations. New York, 1905 (D. Van Nostrand Co.).—This volume opens by describing the rock-making minerals, also the rocks and fossils in so far as they are related to structural geology. Following this are several chapters on the rock structures, such as stratification, faults, mode of occurrence of eruptive rocks and of ore formations. A third part deals with the principles of geological surveying and the economic aspects of geological structure. The work is made very attractive by clear typography, appropriate subdivisions, and by the number and excellence of the illustrations, taken almost entirely from the British Isles, the plates being photographic reproductions. In photographing the rock-types, however, there is a tendency to unnaturally heighten the color contrasts.

Within the limits indicated by the title this is an excellent treatise, the subject matter being well arranged and classified. The chief value is for its outdoor application, the student finding here a good discussion of field methods and a full description of the structures which he is to look for and identify. The subordination of the dynamical to the structural side results necessarily in the causal relations of earth structures and their interpretation from being made prominent. The ultimate significances of the geological facts are thus not well brought out, and as these are the highest significances they should not be lost sight of in geological instruction. However, as the volume does not profess to cover this side of the subject, it should not be urged as a criticism but should merely be called to the attention of educators as not supplying the whole of the inorganic side of the science. As a text-book presenting an excellent account of the facts and field methods upon which geological conclusions are based, it is of value to all students of pure or applied geology.

J. B.

14. *The Clays and Clay Industries of Connecticut*; by GERALD FRANCIS LOUGHLIN. Bulletin No. 4 Connecticut Geol. and Natural History Survey. Hartford, Conn. 121 pp., 13 maps and plates. 1905.—This report gives first the geographical distribution of the Connecticut clays, followed by a discussion on the origin of clays in general and the geological history of the Connecticut clays in particular. It is shown that they were laid down in quiet waters fronting the continental glacier toward the close of the glacial period. The gravels, sands and clays give indications of water levels at 180, 120 and 80 feet above the present level of the sea. The writer ascribes the highest of these to damming by fragments of ice still lingering to the south, as the highest indication of shore lines to the south is only 120 feet above sea level. But in view of Fuller's recent paper on the Geology of Fisher's Island,* the reviewer suggests as not improbable that these high-level gravels and clays may mark a

* Bull. Geol. Soc. Amer., vol. xvi, pp. 367-390, 1905.

deepest stage of the Champlain submergence. If so they are of considerable scientific importance as serving to correlate the stages of ice retreat with the several stages of the Champlain subsidence within the New England states. Having given the geographical distribution and origin of the Connecticut clays, the subject is taken up of the chemistry of clays, the physical properties of clays and their commercial classification. Following this the composition, properties and adaptabilities of the Connecticut clays are given in detail. The lacustrine and estuarine clays, embracing the bulk of the clay deposits, while suited for the best quality of common red brick at low expense, are limited in their uses by high percentage of iron and extremely low fusing point. Part II treats of the clay industries of Connecticut.

The bulletin is well written throughout and is adapted to the comprehension of the intelligent but untechnical reader. The limited time and money appropriated for this work prevent it from being a final study of the subject, as noted in the introduction. Yet the results are of very considerable value, and by calling attention to one of the resources of the state which is, at present, but poorly developed, may ultimately yield a return in industry many times the comparatively small expenditure required for this report.

J. B.

15. *Geology of Western Ore Deposits*; by ARTHUR LAKES, late Professor of Geology at the Colorado School of Mines. 438 pp., 300 illustrations. Denver, Col. (The Kendrick Book and Stationery Co.)—This volume is not written for the specialist but for the intelligent miner or other person interested in the subject of western ore deposits. Introductory chapters review the rock-making minerals, the ore minerals, and the features of structural and dynamical geology connected with ore deposits. A glossary and index serve a useful purpose. The principles of ore deposition and various types of ore deposits are treated, the examples being chiefly drawn from Colorado, with which state the writer is most familiar, but the mining districts of the other western states and of Alaska are also briefly reviewed, and the distinctive features indicated.

J. B.

16. *The Delavan Lobe of the Lake Michigan Glacier of the Wisconsin Stage of Glaciation and Associated Phenomena*; by WILLIAM C. ALDEN. 106 pp., 15 plates. Washington, 1904. Professional Paper No. 34, U. S. G. S.—The author presents in this paper the detailed results of several seasons field work in the southeastern part of Wisconsin on a small tributary lobe of the Lake Michigan glacier. The points of chief interest lie in the proof, based on interlobate phenomena, of the contemporaneity of the Lake Michigan, Delavan, and Green Bay ice lobes and the simultaneous withdrawal of the two latter from their terminal moraines; and in the application to the deposits in this field of the criteria for the determination of the age relationships of the Wisconsin and pre-Wisconsin drift.

A large number of analyses of the drift of this region were made and its lithological character carefully determined therefrom. The interesting result is found that 87 per cent of the material is of local derivation, thus indicating a subglacial origin. The surface boulders are predominantly foreign and therefore probably englacially transported. No essential lithological difference was noted between the drift of terminal moraines, outwash, ground moraines and drumlins.

I. B.

17. *Platinum in Black Sands from Placer Mines*, DAVID T. DAY.—A circular sent out by U. S. Geological Survey in March, 1905, to some 8,000 placer miners, chiefly in the United States, has thus far brought in some 828 samples of black sands; these are largely from the western states and territories, but also from British Columbia, Central America and Mexico. Of these samples, 195 specimens were assayed for gold and platinum with the result of finding platinum in 72 of the specimens. Of these 72, 17 showed only a trace and 14 an amount equal to two ounces or more per ton of concentrate. A sample from Junction City mining district, Trinity Co., Cal., showed 25.8 oz.; one from Oroville, Butte Co., Cal., showed 27.45; and one from Riddle, Douglas Co., Oregon, 128.73 oz. In addition to these tests, 190 samples were examined as to the minerals present with interesting results; polycrase is noted in sands from Idaho Co., Idaho, and columbite and tantalite from Shoshone Co. Field work has also been carried on in the collection and examination of sands of various placer deposits, as also from bars in the Columbia river; important results may be anticipated from this thorough work.

18. *CASSITERITE, a new cleavage, or perhaps parting law*; by WILLIAM E. HIDDEN.—(communicated).—Preliminary announcement is hereby made of my late observation, at the Ross Tin Mine, near Gaffneys, S. C., of a new cleavage (or "parting") in cassiterite. This new cleavage is very common, almost perfect and is parallel to e (101, 1- $\bar{2}$). Very imperfect cleavages parallel to s (111, 1) and m (110, 1) were also noticed, those with s being most common.

Measurements of $e \wedge \bar{e}$ (cleavage surfaces), with hand goniometer, gave $133\frac{1}{2}^\circ$, while the required angle is $133^\circ 32'$. Faces of the new cleavage up to four inches long and over two inches wide were noticed, remarkably smooth and flat. They are very characteristic of the locality. Twins parallel to the well-known twinning plane (e , 101) were not uncommon. Some of these were elongated with the s planes, making what seem to be prismatic planes, similar to sphene, etc. This new tin locality is already credited with having produced about forty tons of cassiterite (yielding over 70% metallic tin) and gives good promise for the future. The associated minerals are albite, microcline (?), amphibole, quartz, biotite, menaccanite, rutile, garnet and probably scapolite, monazite and eudialyte.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Harvard College Observatory*.—Recent publications include the following :

ANNALS, Vol. LIII, No. V, Phoebe, the ninth Satellite of Saturn ; by WILLIAM H. PICKERING.

No. VI; Investigation of the Orbit of Phoebe ; by FRANK E. ROSS.

No. VII, Second Supplement to Catalogue of Variable Stars.

No. VIII, Martian Meteorology ; by WILLIAM H. PICKERING.

No. IX, The ninth and tenth Satellites of Saturn ; by WILLIAM H. PICKERING.

Vol. LVI, No. III. The Spectrum of Nova Persei, No. 2.

CIRCULARS. No. 93, The 24-inch Reflecting Telescope.

No. 94, Variability of Eunomia (15).

No. 95, Brightness of Jupiter's Satellites.

No. 96, 843 new variable Stars in the small Magellanic Cloud.

No. 97, Bruce Photographs of Planets.

No. 98, Stars having peculiar Spectra.

No. 99, A probable new Star, RS Ophiuchi.

No. 100, Variable Stars in the Clusters Messier 3 and Messier 5.

No. 101, Positions of Ocello (475) during 1904.

No. 102, Positions of Phoebe in May, 1904.

No. 103, Positions of Ocello (475) during 1905.

No. 104, H 1174. A new Algol Variable, 035727.

2. *Publications of the Cincinnati Observatory*. No. 15, *Catalogue of 4280 Stars for the Epoch 1900* ; by JERMAIN G. PORTER, Director. 100 pp. Cincinnati, 1905 (University of Cincinnati).—The stars included in this volume are all those of Piazzi's catalogue which were north of the equator in 1800 except those contained in the Berlin Jahrbuch and eighteen of the Pleiades group ; stars observed by Piazzi, but not given in his catalogue, are also included.

3. *Report of the Director of the Yerkes Observatory, University of Chicago* ; by Professor GEORGE E. HALE. 1, for the period July 1, 1899 to June 30, 1902, pp. 32. 2, for the period July 1, 1902 to June 30, 1904, 8 pp.—These reports, though presented in very concise form, give a clear summary of the various lines of important work carried on at the Yerkes Observatory during the five years from 1899 to 1904.

4. *Carnegie Institution of Washington*.—Recent publications from the Carnegie Institution include the following :

No. 8. Bibliographical Index of North American Fungi ; by WILLIAM G. FARLOW. Vol. I, Part I, Abrothallus to Badhamia, Pp. xxxv, 312, 8vo. Washington, Sept. 1, 1905.

No. 25, Evolution, Racial and Habitudinal ; by Rev. JOHN T. GULICK. Pp. xii, 269, 8vo. Washington, August, 1905.

No. 27. Bacteria in Relation to Plant Diseases ; by ERWIN F. SMITH, in charge of Laboratory of Plant Pathology, Bureau of Plant Industry, U. S. Department of Agriculture. Volume I,

Methods of work and general literature of Bacteriology exclusive of Plant Diseases. Pp. xii, 285, 4to, with 31 plates and 146 text-figures. Washington, September, 1905.

5. *Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures and condition of the Institution for the year ending June 30, 1904.* Pp. lxxix, 804, with numerous plates and text-figures.—The advance report of the Secretary, Professor S. P. Langley, was noticed in the number for March, on page 261. The complete volume now issued contains this administrative report, occupying the first one hundred pages, and also following a general appendix, pp. 109–791, containing, as usual, a series of articles. These give brief accounts of important scientific discoveries, also reports of investigations made by the workers connected with the Institution, and some more extended papers on special subjects of interest to the correspondents of the Institution. The volume closes with biographical notices of Sir George G. Stokes, Professor von Zittel and Professor Karl Gegenbauer.

6. *Catalogue of the Collection of Birds' Eggs in the British Museum of Natural History.* Volume IV, *Carinatae (Passeriformes continued)*; by EUGENE W. OATES assisted by Capt. SAVILLE G. REID. Pp. xviii, 352, with 14 colored plates. London, 1905.—This fourth volume of the British Museum Catalogue of Birds' Eggs corresponds with the fourth volume of Dr. Bowlder Sharpe's Hand-list of Birds. The number of species included is 620, represented by 14,917 specimens.

7. *Bibliotheca Zoologica II. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861–1880 selbständig erschienen sind*; bearbeitet von Dr. O. TASCHENBERG. Siebzehnte Lieferung.—The sixth volume of this comprehensive work is completed with the present part. Like the parts immediately preceding, it is devoted to the twenty-second section of the entire field, that of Paleozoology, which it brings to a close. The volume, title page, dedication, and table of contents are also included.

OBITUARY.

BARON FERDINAND VON RICHTHOFEN died on October 7th, at the age of seventy-two years.

PROFESSOR LEO ERRERA, Professor of Botany in the University of Brussels, died on August 1, at the age of forty-seven years.

Mr. G. B. BUCKTON, F.R.S., the English Entomologist, died on September 26, at the age of eighty-eight years.

M. ELISÉE RECLUS, the eminent French geographer, died in July last in his seventy-sixth year.

THE
AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLI.—*Two New Ceratopsia from the Laramie of Converse County, Wyoming*; by J. B. HATCHER. (With Plates XII, XIII.)

[From a Monograph on the Ceratopsia by J. B. Hatcher. Published by permission of the Director of the U. S. Geological Survey.]

Editorial note.—In the course of his extensive study of the Laramie Ceratopsia contained in the U. S. National Museum and in that of Yale University, Mr. Hatcher discovered two forms which were new to science. These he described in the above mentioned monograph, giving to the first, an undoubted Triceratops, a new specific name, while for the second specimen, which represents a new genus as well as species, no name was suggested by the author. The duty of naming this form devolves therefore upon the editor. The generic name *Dicera-tops* is suggested by the lack of a nasal horn, while the specific name *hatcheri* will serve to commemorate Mr. Hatcher's work in connection with this remarkable type.

In view of the recent discoveries among these most interesting forms, it has been deemed advisable to publish these descriptions at the present time without waiting for the publication of the monograph.—RICHARD S. LULL.

Triceratops brevicornus sp. nov.

Plate XII, Figures 1 and 2.

Type No. 1834, Yale Museum.

Char. Specific: Supraorbital horn cores short and stout, not much compressed, nearly circular in cross-section. Nasal horn core short and stout with the anterior border vertical instead of being directed upward and forward at an angle of 30 degrees. Vertical and longitudinal diameters of lateral temporal foramen nearly equal. Orbit irregularly elliptical in outline with the longer axis running from above downward and forward. Postfrontal fontanelle open even in old individuals.

The type, No. 1834, Yale Museum, of the present species consists of a nearly perfect skull with lower jaw and a com-

AM. JOUR. SCI.—FOURTH SERIES, VOL. XX, No. 120.—DECEMBER, 1905.

plete series of presacral vertebræ, together with a number of ribs more or less complete, and portions of the pelvis, including a portion of the right ilium and a nearly complete pubis. The vertebral series lay in position with the vertebræ interlocked by their zygapophyses from the axis to the last dorsal, though portions of some of the vertebræ had weathered away when found. Behind the posterior dorsal, impressions of the centra of the first two sacra were preserved in the hard sandstone in which the skeleton was imbedded.

Locality.—The skeleton was discovered by Mr. W. H. Utterback, and the exact locality was some three miles above the mouth of Lightning Creek and about one and a half miles south of that stream, in Converse County, Wyoming. The horizon was near the summit of the Laramie, and the specimen was collected by the present writer assisted by Messrs. W. H. Utterback, A. L. Sullins, and T. A. Bostwick. When discovered the skeleton lay imbedded in a hard sandstone concretion and was much shattered and weathered about the pelvic region. None of the limb bones and no part of the tail were recovered.

The Skull.

The extremely rugose nature of the skull together with the closed condition of the sutures, many of which are almost or entirely obliterated, make it certain that the type of the present species pertained to an old individual.

The Cranium.—The chief distinctive features of the cranium are as follows: The supraorbital horn cores are unusually short and stout, especially at the base. They are less compressed and more nearly circular in cross-section than in most other species. The nasal horn is short and very stout with the antero-posterior diameter much exceeding the transverse. Its anterior border is directed upward in a line perpendicular with the longer axis of the skull instead of forward and upward at an angle of about thirty degrees to that axis as in the type of *T. prorsus*. The lachrymal foramen, as in *T. serratus*, lies between the maxillary and the nasal, but in the present species its anterior half is entirely enclosed by the maxillary, that bone sending upward a short process alongside the premaxillary process and forming the anterior one-half of the superior border of the foramen. The orbit is elliptical in outline with the longer diameter inclined backward from the perpendicular at an angle of about ten degrees. The lateral temporal fossa is triangular in outline, its respective borders describing nearly an equilateral triangle, the fore and aft diameter only slightly exceeding the vertical. The rostral bone is heavy and very deeply excavated beneath. The epijugal is rather

acutely pointed and regularly triangular in cross-section. The infratemporal arch, as in *T. serratus*, is formed by the quadrate with overlapping processes from the jugal and squamosal, that from the latter element occupying a slightly more elevated position in the type of the present species than in that of *T. serratus*. The exoccipital process extends distally beyond the quadrate and projects as a small angular process. There are six exoccipitals, borne wholly on the squamosal, and at least three more between the last of these and the single median one situated at the median parietal region. Though the frill is not sufficiently perfect in this region to determine the number of epoccipitals with accuracy, there cannot be fewer than nineteen. The postfrontal fontanelle is large and circular in outline. The median longitudinal crest of the parietals is well defined and bears the usual rugosities. Near the apex the right horn core has been worn into a peculiar form by the action of wind, sand and water while it protruded from the sandstone concretion in which it was found prior to its discovery. The palatal view shows no characters essentially different from those of other species of this genus. In the region of the supraoccipitals and parietals the sutures are so obliterated by age and obscured by distortion and crushing that it is quite impossible to determine their nature.

The Lower Jaw.—The lower jaws with the prementary were in position and in a splendid state of preservation. The prementary is rather longer than is common. On the superior surface of the mandibular fossa near the anterior end two large foramina pierce the wall and pass upward toward the dental chamber. The splenial is very broad posteriorly and entirely encloses the mandibular fossa, except at the opening of the internal mandibular foramen. The coronoid process is low and stout and superiorly it is produced forward into a broad and somewhat decurved projection. At its greatest expansion the superior border of the splenial covers over for a short distance the series of dental foramina on the inner side of the dentary. The principal characters of the skull are well shown in Plate XII, figures 1 and 2.

The Vertebrae.—The vertebrae will be fully described in that portion of the monograph relating to the osteology of the genus *Triceratops*.

Principal Measurements of Type of T. brevicornus (No. 1834, Y. M.).

Greatest length of skull	1652 ^{mm}
Greatest breadth of frill	1120
Expanse of jugal	600

Diceratops hatcheri Lull, gen. et sp. nov.

Plate XIII, Figures 3 and 4.

Mr. Hatcher's description is as follows :

"*Char. Generic:* Nasal horn core absent. Squamosal bones pierced by large fenestræ, while smaller ones penetrate the parietals. The inferior border of the squamosal lacks a quadrate notch.

Type No. 2412, U. S. National Museum.

"*Char. Specific:* Supraorbital horn cores short, robust, and nearly circular in cross-section at base, erect and but slightly curved. Orbits project in front of the horns, the frontal region lying between the horns being concave. Exoccipital processes slender and widely expanded.

"*The type*, No. 2412, of the U. S. National Museum, consists of a skull without the lower jaw. The posterior portion of the frill is somewhat weathered but the specimen appears to have suffered comparatively little from crushing.

"*Locality:* The specimen was found in a hard sandstone concretion about three miles southwest of the mouth of Lightning Creek, Converse County, Wyoming. When found the concretion in which the shell was imbedded had entirely weathered out of the surrounding sandstone and stood at an altitude of five or six feet above the ground, firmly attached beneath to another concretion. The skull stood on its nose with the frill pointing upward.

"*The Skull:* The chief distinctive features of the skull are as follows: The supraorbital horn cores are comparatively short, robust, and nearly circular in cross-section at the base instead of compressed, as in most other species. They rise more directly upward than in other species and are only slightly curved. The orbits also occupy a position more anterior than that seen in other species; the anterior borders of the horn cores rise from about the middle of the superior borders of the orbits so that the orbits project well in front of the horns. The frontal region between the orbits is concave. The exoccipital processes are rather slender and widely expanded.

"The nasals terminate anteriorly in a rounded rugosity not developed into anything approaching a nasal horn and resembling that of the type of *Triceratops obtusus*. The rostral bone is small and firmly coössified with the premaxillaries. The latter are elongate but not deep. The maxillaries are massive and the lachrymal foramen is elongate and below and considerably forward of the orbit. The jugal is broad distally and firmly coössified with the epijugal. The lateral temporal fossa is nearly as deep vertically as longitudinally. The squa-

mosal is elongate, and just posterior to the quadrate groove it is pierced by a large fenestra. The antero-inferior angle is little produced and there is no quadrate notch, the inferior border in this region describing widely an open concavity. The parietals are broad and thin and, on either side of the median line about 235^{mm} in front of the posterior border, there is an elongated fenestra with a longitudinal diameter of 150^{mm} and a greatest transverse diameter of 52^{mm}. This fenestra is completely enclosed on the right side, but on the left the parietal is injured in this region. In the drawings it has been restored from the right side. The supra-temporal fossa is elongate. There is a single median postfrontal fontanelle as in *Triceratops*, but posteriorly this gives origin to two deep channels, one on either side. These run backward along the surface of the parietal and terminate in two small circular fontanelles, conditions very similar to those which obtain in *Torosaurus*.

Measurements of the type.

" Distance from anterior end of rostral to posterior of squamosal	1990 ^{mm}
Distance from anterior end of rostral to anterior of orbits	845
" " inferior border of orbit to lower end of jugal	363
" " posterior border of nasal opening to extremity of beak	614
Distance from posterior border of orbit to posterior surface of horn core	175
Distance between anterior borders of orbits	340
Circumference of supraorbital horn cores at base	610
" " " " mm. above orbit	340
Vertical diameter of orbits	165
Antero-posterior diameter of orbits	125"

[*Note*.—This genus is most nearly allied to *Triceratops* and is distinguished therefrom mainly by the much smaller rostral bone; by the absence of a nasal horn, which in all species save *T. obtusus* is fairly well developed; by the very erect, short, robust, supraorbital horn cores which seem to take their origin much further back with relation to the orbit; by the concavity of the frontal region between the orbits and by the peculiar form of the postfrontal fontanelle. The general proportions of the skull resemble *Triceratops* rather than the contemporary genus *Torosaurus*, in which the great frill so preponderates over the comparatively abbreviated facial region. The parietals resemble those of *Triceratops* except for the presence of the small fenestræ on either side of the median line.

The squamosals differ from those of *Triceratops* in the conformation of the lower border, which lacks the quadrate notch, and in the presence of the unique fenestræ.

Aside from the general proportions of the skull, *Diceratops* and *Torosaurus* differ in the presence in the former of separately ossified epoccipital bones around the margin of the frill. These ossicles are apparently entirely lacking in *Torosaurus*. The two genera agree in the possession of parietal fenestræ though these are evidently not homogenous. They also agree in the form of the postfrontal fontanelle.

While I believe *Diceratops* to be a valid genus, I am not inclined to lay the stress upon the parietal and squamosal fenestræ which Hatcher does, as they may possibly be pathologic. Those of the squamosal bones, which are found in no other form among *Ceratopsia*, are not of the same size, while only one is known in the parietals for the sufficient reason that the bone is broken away on the left side where the fenestra would come if present, and it is quite possible that it may never have existed.

There is preserved in the Museum at Yale University a *Clasaurus* scapula with a clean cut foramen through it with perfectly healed edges. This foramen is not present in the other scapula from the same individual and Professor Marsh used to say that the perforation was caused by a *Triceratops* horn. This certainly seems suggestive of the manner in which the *Diceratops* fenestræ may have arisen.

RICHARD S. LULL.

Amherst, Mass.]

DESCRIPTION OF PLATES.

PLATE XII.

Skull of the type specimen of *Triceratops brevicornus* Hatcher. No. 1834, Yale University Museum. One-sixteenth natural size.

FIGURE 1.—Lateral view. *ang*, angular; *art*, articular; *cp*, coronoid process; *D*, dentary; *ep*, epoccipital; *ju*, jugal; *lf*, lachrymal foramen; *mx*, maxillary; *no*, nasal opening; *nh*, nasal horn core; *o*, orbit; *pa*, parietal; *pd*, predentary; *pmx*, premaxillary; *qu*, quadrate; *r*, rostral bone; *sang*, surangular; *sq*, squamosal; *soh*, supraorbital horn core.

FIGURE 2.—Palatal view. *dc*, dental channel; *exo*, exoccipital; *ju*, jugal; *mx*, maxillary; *pa*, parietal; *pal*, palatine; *pmx*, premaxillary; *pt*, pterygoid; *qu*, quadrate; *r*, rostral bone; *sq*, squamosal; *BO*, basioccipital; *C*, occipital condyle.

PLATE XIII

Type skull of *Diceratops hatcheri* Lull. No. 2412, U. S. National Museum. One-sixteenth natural size.

FIGURE 1.—Lateral view. *ep*, epoccipital; *lf*, lachrymal foramen; *mt*, maxillary teeth; *mx*, maxillary; *n*, nasal; *NO*, nasal opening; *o*, orbit; *pa*, parietal; *pmx*, premaxillary; *qu*, quadrate; *r*, rostral bone; *SF*, squamosal fenestra; *soh*, supraorbital horn core.

FIGURE 2.—Dorsal view. *ep*, epoccipital; *lf*, lachrymal foramen; *n*, nasal opening; *o*, orbit; *pa*, parietal; *paf*, parietal fenestra; *pf*, postfrontal fontanelle; *r*, rostral bone; *SF*, squamosal fenestra; *sq*, squamosal; *soh*, supraorbital horn core.

ART. XLII—*Restoration of the Horned Dinosaur Diceratops*; by RICHARD S. LULL. (With Plate XIV.)

THE new genus and species described by Hatcher in the preceding article represents perhaps the most bizarre and grotesque form among all the race of horned dinosaurs, and the author has attempted an interpretation for the purpose of emphasizing the features wherein this animal differed from any of its allies.

Diceratops comes from the Laramie of Converse County, Wyoming, and while contemporaneous with *Triceratops* and *Torosaurus* it is probably as late in geological time as any of the species of either genus, and may be said to represent the culmination of at least one phylum of the Ceratopsia. *Diceratops* differs from *Torosaurus* in the proportions of the skull, for in the latter genus the frill is relatively huge as contrasted with the abbreviated facial region. In this *Diceratops* and *Triceratops* agree, and it is quite evident that there is a genetic relationship between these genera, while *Torosaurus* represents a totally distinct phylum.

Perhaps the most notable point of distinction between *Triceratops* and *Diceratops* is the presence of a fairly well developed nasal horn in the former while in the latter genus it is lacking, a feature which in the author's mind represents the culmination of specialization.

The earliest known Ceratopsia are the Judith River types, characterized by an incomplete frill, by rudimentary horns above the eyes, and by a very well developed, generally erect or backwardly curved nasal horn.

The supraorbital horns are progressive structures while the nasal horn is retrogressive, and during the lapse of time between the Judith River and Laramie periods, when the marine Bearpaw shales and Fox Hills sandstones were laid down, the Ceratopsia underwent a remarkable though unrecorded evolution, for when they again come into view in the Laramie the armament is reversed, in that the great temporal horns are by far the larger and more efficient weapons, and the diminishing nasal horn, while supplementing the others in the various species of *Triceratops* and *Torosaurus*, is vestigial in the form under discussion.

This change of armament was necessarily accompanied by a change in the method of attack, for while the Judith River types probably used the one horn much as the rhinoceros does, with an upward thrust, *Triceratops* seems to have charged with lowered head, the small forwardly directed nasal and the larger

supraorbital horns meeting the enemy at the same moment of impact. The frill now becomes of greater protective value instead of affording leverage merely for the muscles of the neck.

Diceratops exhibits the extreme of development of this style of warfare, for the supraorbital horns are the sole aggressive weapons while the widely expanded frill served admirably to withstand the shock of the adversary's horns. We have here a precise analogy with the knight of old tilting with his spear and shield.

The skull of *Diceratops* shows the horns to be very erect, much more so than in *Triceratops*, so that the head would have to be carried much lower in charging than in the latter genus and the horns through relatively short are extremely powerful. I have indicated a callosity, the last vestige of a horn, over the nasals, for they still remain very highly arched and evidently bore some of the impact of the adversary's blow. The eyes were set in deep thick-rimmed sockets which look directly outward, evidently limiting the forward range of vision, but affording ample protection to these highly necessary organs.

If one will turn to Hatcher's figure of the *Diceratops* skull (Plate XIII, figures 1 and 2), he will notice in the frill several apertures which Hatcher has called "fenestræ." Two of these are through the squamosal portion of the frill, one on either side, and one through the parietal.* They are irregular in size and in position, and while the Judith River types and *Torosaurus* among the Laramie forms have *parietal* fenestræ, they are large and symmetrical, and there is no instance of *squamosal* fenestræ in any known genus of *Ceratopsia*. If the author's conception of the final function of the frill is correct, there would be no reason for the development of apertures through it, which would only tend to weaken it and mar its usefulness. It seems vastly more probable that these are "old dints of deep wounds" received in combat. None of them, not even the great one on the left, were necessarily fatal, as they all seem to be through the free portion of the frill, and, while the bone was destroyed, the horny or leathery integument may have grown again over the gap as indicated in the model. The edge of the apertures are healed, showing that the animal lived for some time after the injuries were received.

I have represented the gape of the mouth with much less

* Mr. C. W. Gilmore, who prepared the type specimen of *Diceratops*, is by no means sure of the "parietal fenestra." There was no bone adhering to the matrix at that point so he left the opening through the frill for want of evidence to the contrary. The bone forming the margin of the left squamosal aperture is decidedly pathologic.

backward extent than in other restorations of *Ceratopsia*. Here we cannot be guided by the form of the mouth in existing reptiles, for none living have the same feeding habits as these dinosaurs. Here the mouth may properly be divided into an anterior prehensile portion, the turtle-like beak, and a posterior masticating portion, the dental armature. In herbivorous mammals the gape only includes the prehensile and never the masticating portion, because of the necessity of muscular cheeks to retain the food in the mouth. The *Ceratopsia* had a dental apparatus which chopped the food into short lengths, and the pieces, falling outside of the lower jaw, would have been lost had the gape extended backward beyond the beginning of the tooth series.

Massachusetts Agricultural College, Amherst.

ART. XLIII.—*Triassic System in New Mexico*; by CHARLES R. KEYES.

THE "Red Beds" of the Southwest, from central Kansas to the Grand Canyon, have long defied every attempt to determine their geological age, and to satisfactorily settle even the larger problems connected with their stratigraphy. In Kansas, in Oklahoma, in Texas, and on through New Mexico and Arizona to Utah, these formations have for more than half a century remained a puzzle. Those who have had to give some attention to the Red Beds have, in the absence of abundant characteristic fossils, considered the entire sequence either Triassic in age or (so-called Permian) Carboniferous.

Since the making of extensive examinations of the Red Beds formations over broad areas in New Mexico and the adjoining states during the past few years, it has been found that there are a number of important general features that have either not received the attention they deserve, or have escaped notice altogether. When two years ago I made the statement* concerning the Kansas section, that after seeing at close range the Red Beds of New Mexico sufficient data had been obtained to clearly demonstrate that their stratigraphy could not be unraveled on the basis of the Kansas scheme, the separation of the Red Beds into their component parts was then beginning to resolve itself into a satisfactory reality.

The Red Beds do not form the homogeneous succession that they have been generally regarded as doing. Lithologically they are broadly divisible into two easily distinguishable parts. There is a large portion of the entire section composed of heavy argillaceous shales and clayey sandstones usually of deep red colors, rather uniform throughout, with much gypsum intercalated and disseminated, and with saline shales abounding. The upper part consists of light, sandy shales chiefly, with some heavy sandstones; the colors, while prevalently reds, are quite varied; gypsum and saline shales are present only sparingly. The plane separating the two parts of the Red Beds section, as thus defined, is, when once recognized, a conspicuous one.

In eastern New Mexico, in the Canadian and Pecos valleys, around the northern and western margins of the Llano Estacado, there is at the base of the upper one of the two terranes a well marked conglomerate that has been widely traced. Unconformable relationships exist between this and the strata beneath. In western Texas, Drake† and Cummins have also well established these facts.

* *American Geologist*, vol. xxxii. pp. 218-223, 1903.

† *Texas Geol. Sur., Third Ann. Rept.*, p. 227, 1892.

In western New Mexico, in the Zuni uplift, there exist, as was first shown by Dutton,* similar conditions, except that the evidences of unconformities have not as yet been noted, and in fact no attempt has yet been made to look carefully for them. Between the two lithologically different parts of the Zuni section of the Red Beds there also exists an important conglomerate which the author just mentioned correlates with Powell's Shinarump conglomerate of the Grand Canyon, and which is considered the base of the Triassic of that district.

According to all available data, derived from the biologic contents, which at best are rather meager, the stratigraphic relationships, and lithologic characters, there is a lower portion of the Red Beds belonging to the so-called Permian (Carboniferous) and an upper portion which appears to be Triassic in age.

One great difficulty which has been encountered in the consideration of the Red Beds in the southwestern United States has been the existence of a great erosion interval during Early Cretaceous times when the Red Beds suffered severely from planing off during the period when they constituted part of a vast land area. This fact has only lately been fully appreciated,† and its full significance grasped.

The three general sections of western, central and eastern New Mexico may be paralleled as in the subjoined table:

GENERAL RED BEDS SECTIONS IN NEW MEXICO.

Western Section.		Central Section.		Eastern Section.	
Dakota sandstones..		Dakota ss.		Dakota sandstones..	
Wanting		Wanting		Comanche sandstones	300
Zuni shales	1200	Wanting		Pyramid shales	100
Wingate sandstones	800	Wanting		Amarillo sandstones	200
Shinarump shales ..	1500	Wanting		Endee shales.....	300
Moencopie shales...	500	Wanting		Cimarron shales.....	1000
Madera limestones .		Madera li.		Not exposed.....	

The geographic distribution of the Triassic beds presents some special points of interest. East of the Rio Grande the Carboniferous part of the Red Beds probably greatly predominates over the Triassic portion. West of that stream the latter no doubt has very much the larger section. Owing to extensive erosion that took place over the Red Beds district, at least throughout much of what is now New Mexico, before the deposition of the Dakota sandstone, a large portion of the Triassic portion must have been removed. It may be that part of this erosion took place just prior to Triassic times, as the conglomerate bed 500 feet above the base of the Red Beds

* U. S. Geol. Sur., Sixth Ann. Rept., p. 135, 1886.

† This Journal (4), vol. xviii, pp. 360-362, 1904.

section in the Zuni region and in the middle of the section in eastern New Mexico would indicate.

In the Canadian valley, at the eastern border of New Mexico, the sediments of the Triassic system are well represented at the top of the Red Beds section. Farther westward, where the Rio Pecos cuts the Glorieta escarpment, Newberry distinguished both Triassic and Permian (Cimarron) plant remains.

Around the entire escarpment of the Llano Estacado, or Staked Plains, in eastern New Mexico and western Texas, embracing an area of over 50,000 square miles, the Triassic beds are more or less well exposed. The New Mexico portion of this belt is 300 miles long. The greater part of the Red Beds section seen in the Canadian and Pecos valleys is of Triassic age. Only in the bottom of these valleys is the Carboniferous part of the Red Beds found.

It now seems quite likely that within the boundaries of Kansas none of the Red Beds section can be considered as being of Triassic age. Early Cretaceous erosion, which bevelled off the Red Beds, appears to have removed the Triassic strata altogether east of the New Mexico line and north of the Canadian river. The youngest layers of the Early Cretaceous (Comanche series) in overlapping northward on the old, even, erosion-surface, now appear to rest, in southern Kansas, on the lower part only of the Red Beds.

West of the Rio Grande, in north-central New Mexico, along the Chama river, at the locality known as Abiquiu, Newberry and Cope regarded a very thick Triassic section to be represented. Around the Zuni mountains is an important belt of Triassic strata, which according to Dutton are more than 3500 feet in thickness.

As detailed mapping of the region goes on, the beds which have been considered as belonging to the Triassic system will be found to have a very much wider geographic distribution than is at present known, and many new localities will doubtless be discovered in which these strata are well represented.

In eastern New Mexico the basal plane of the Triassic appears to be well established at the bottom of a well-marked conglomeratic sandstone which separates the lower, dark red, clayey Red Beds from the upper, light reddish, sandy portions. At the base of this conglomerate there are abundant evidences of unconformable relationships between the two parts of the section.

These relationships are well displayed along the northern magnificent escarpment of the Llano Estacado, which forms the south side of the Canadian valley. Drake,* who has traced the formation along the entire length of this great wall, and

* Texas Geol. Sur., Third Ann. Rept., p. 229, 1892.

who has examined its details rather carefully, says regarding the character of this unconformity: "The slight difference in dip, and sudden change in lithological character of the Triassic beds from the Permian, point conclusively to a break in the sedimentation of the two formations. At some localities the Triassic beds are overlain by Cretaceous, but generally by Tertiary material. The Cretaceous escarpments or buttes resting on the Triassic beds are often two hundred feet thick, and mostly limestone. The denuding forces that for an immense length of time were cutting these Cretaceous rocks back towards their present limits must have carried away a great deal of the Triassic before it was covered by Tertiary. The strata thus enclosed between two unconformable beds must of necessity vary in thickness, and so we find it varying from a few feet to nearly four hundred feet. Even in localities close together the beds vary considerably in thickness. The average, however, will probably reach two hundred feet."

Of the appearance of the two formations a short distance east of the New Mexico line the same writer* observes: "The contact between the Dockum beds and the underlying Permian is clearly marked. Both the color and lithological characteristics of the two formations bear a striking contrast. The Permian is a bright red argillaceous sand, slightly shaly, though sometimes massive, is characteristic for stratification planes, and below the top forty feet is interstratified with massive and fibrous gypsum, the gypsum becoming more abundant toward the base of the section exposed. The Dockum beds, arenaceous clays, in contact are a yellowish purple or a yellowish red, sometimes decidedly yellowish. The bedding is usually uniform and lacks the stratification planes so characteristic of the Permian. The contrast between the formations along their contact is so great that the contact may be located as far as the eye can see stratification planes in the freshly eroded outcropping bed, or as far as it can distinguish sharply contrasting colors."

The upper limiting horizon of the Triassic section is well defined. In the east, around the Llano Estacado in the Canadian and Pecos valleys, the superjacent formations are beds of the Comanche series of the Early Cretaceous. A little farther to the westward the massive Dakota sandstone of the Mid-Cretaceous age is the capping member. West of the Rio Grande there comes in between the Wingate division of the Triassic Red Beds and the undoubted Dakota sandstone a series of red and white shaly sandstones having a thickness of 1,200 feet, the exact age of which is at present not definitely determined. This formation is thought to belong to the Tri-

* *Ibid.*, p. 241.

assic system. It is not impossible that it is Jurassic or Cretaceous in age. It is the beginning of a great formation which extends a long distance to the northwestward into Arizona, western Colorado and Utah and which has been regarded as representing the Jurassic period.

East of the Rio Grande a very marked plane of unconformity separates the Dakota sandstone from the Red Beds beneath. This break in sedimentation represents a profound erosion period, to which more detailed reference is made in another place.

The stratigraphic extent of the Triassic strata in eastern New Mexico embraces about 500 feet of the general geological section. In the west the vertical measurement is very much greater. Dutton places it at 3,500 feet.

As regards correlation of the Triassic formations, that portion of the Red Beds which has been regarded as of Triassic age may be compared, on the one hand, with the cognate beds of the Texas section, and on the other with the enormous thicknesses of Triassic strata in Arizona, Utah and Colorado.

The standard section of the Triassic in New Mexico should be considered typically developed in the northwestern portion of the region, where the section is most complete and most extensive. In comparing this sequence with the Texas, Oklahoma and Kansas sections of the Red Beds there are presented some difficulties of an unusual kind. The planing off of the folded Paleozoics including the Red Beds in great part, during the erosion interval which existed in the eastern New Mexico region just before the deposition of the Dakota sandstone, removed a very large portion of the formation.

As at present understood, the general relationships of the Carboniferous part of the Red Beds, the Triassic Red Beds, and the associated formations are best indicated by diagram as given below.

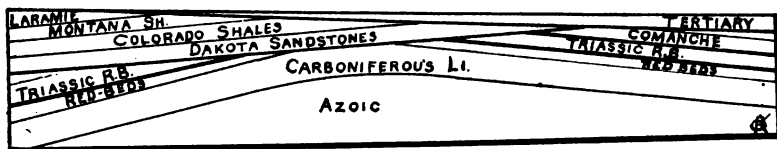


FIG. 1.—Relationships of the Triassic Formations in the southern Rocky Mountains.

The cross-section traverses New Mexico in a nearly east and west direction, passing through the Cerro Tucumcari and the Zuni mountains.

Owing to mountain-making movements which took place in the region in the latest Carboniferous or in Early Cretaceous

times, or possibly in both, the Paleozoic formations and Triassic beds were bowed up, somewhat folded and faulted and then eroded off as a land surface. When Mid-Cretaceous (basal part of "Upper") beds were laid down, they were deposited largely on this old land surface worn out on the bevelled edges of the older formations.

In the east there are shown marked unconformable relationships not only between the Cimarron Red Beds and the Triassic Red Beds, but between the latter and the Comanche series, between the last mentioned and the Dakota sandstone series, and between all of these and the Tertiary formations.

In central New Mexico, the Dakota series rests directly on the Madera limestones of the Carboniferous. The Red Beds of both the Cimarron series and the series of the Triassic have been entirely removed through Early Cretaceous erosion. The Comanche series, which had been constantly encroaching upon the old land area from the beginning to the end of its period of deposition, did not reach this far. In consequence the Mid-Cretaceous sandstones (Dakota) were deposited directly upon the Carboniferous limestones (Madera).

In the west the sequence was very much as it was in the east, except that the Early Cretaceous appears to be entirely missing, the Triassic section very much thicker, and the Cimarron section very much reduced.

It is a singular fact that the tripartite character of the Triassic sections in the west has a triple counterpart in the east. No direct connection between the two sections has been actually traced in this field, for in central New Mexico a wide gap exists.

Comparing the eastern section with the sections of the adjoining portions of Texas, this agreement is very close. The entire Triassic section is there called the Dockum beds. As already stated, it is not believed that any portion of the Red Beds of Kansas are represented by the Triassic formations of New Mexico.

In the Zuni uplift, where the Triassic beds are so well displayed, they come up from beneath the vast field of Cretaceous sandstones. The sequence between the so-called Permian Red Beds and the Dakota sandstones of the Cretaceous is very thick. The data upon which the geological age has been determined have been already given. Dutton, who a quarter of a century ago had perhaps given the subject more attention than anyone else, was unable to satisfactorily separate the two parts. He says that the "Triassic system of New Mexico cannot be correlated so easily with its cognate beds in southern Utah and the Grand Canyon district as the Carboniferous and Permian. In the former region it has yielded but few fossils, while in the

latter it has yielded none at all. We have here as well as there only an arbitrary provisional horizon for its base, and we are if possible still more uncertain where to assign its summit. The paleontological doctors disagree, and who therefore shall decide? It all hinges upon the question whether the Jurassic system has any representatives in this region. If not, then the summit of the Trias can be established at once. But if the upper portion of the enormous series of sandstones and gypsum beds which lies between the Shinarump conglomerate and the lower Cretaceous sandstone is Jurassic, the problem must wait for a solution.”*

Of the Zuni section of the Triassic system it may be that only the lower portion is represented east of the Rio Grande. The upper part of this section has been regarded as belonging to the Jurassic age; but until fuller data are obtained it does not appear advisable to recognize the Jurassic system in this part of the country. For the present, at least, all of this part of the sequence will be considered as a portion of the Triassic succession.

New Mexico School of Mines,
Socorro, New Mexico.

* U. S. Geol. Sur., 6th Ann. Rept., p. 135, 1886.

ART. XLIV.—*Structure of the Upper Cretaceous Turtles of New Jersey*:* *Agomphus*; by G. R. WIELAND.

THE genus *Agomphus* was first proposed by Cope for the reception of Leidy's *Emys firmus* and *Adocus petrosus* and *Adocus turgidus*,† all of which are based on very fragmentary and scanty remains from the Upper Cretaceous marl beds of New Jersey, indicating a genus of heavy shelled turtles next related to *Adocus*. Two of these original types, *A. petrosus* and *A. turgidus*, are now conserved in the Cope Collections in the American Museum of Natural History, where the writer has been extended the courtesy of seeing them, together with the allied *Adocus pectoralis* Cope. An additional type from the Tertiary of Georgia, *Amphiemys oxysternum*,‡ is no doubt correctly referred to *Agomphus*, but has not been accessible. Since the brief descriptions unaccompanied by figures were given by Cope, the only addition to the very meager knowledge of *Agomphus* was made by Baur,§ who briefly noted in addition to the close relationship to *Adocus* and inclusion in the Adocidæ as next related to the existing Central American Dermatemydidæ, the peculiar costiform processes and the interesting fact that *Agomphus* includes forms with relatively the heaviest carapace and plastron known. These latter facts were doubtless based on the specimens of the Marsh Collection obtained about the same time as the Leidy and Cope material, but never formally described or further mentioned although now found to make possible a complete description of the structure of the carapace and plastron, and to include at least two new species and a toptype as follows:

Agomphus tardus Wieland (sp. nov.). (Figures 1-7.)

By far the best specimen of the Marsh collection referable to the genus *Agomphus* is that numbered 774 (Accession No. 323), and now made the type of the new species *A. tardus*. This fine fossil was obtained from the Pemberton marl pits at Birmingham, Burlington County, New Jersey, in 1869. It is of especial interest as affording the structural characters of the

* The first paper of this series, on *Adocus*, *Osteopygis*, and *Propleura*, appeared in this Journal, vol. xvii (pp. 112-132, pl. I-IX), Feb. 1904, and the second on *Lytoloma*, in vol. xviii (pp. 183-196, pl. V-VIII), Sept., 1904.

† The description of these forms under the generic name *Emys* appears on pages 125-8 of Cope's Synopsis of the Extinct Batrachia, Reptilia and Aves of North America. Philadelphia, August, 1869.—*Agomphus* in Suppl't, 1871.

‡ On a New Species of Adocidæ from the Tertiary of Georgia; by E. D. Cope. Proc. American Phil. Soc., vol. xvii, July, 1877, pp. 82-4.

§ Notes on some little known American Tortoises (on pp. 429 and 430), Proc. Acad. of Natural Sciences, Philadelphia, 1891 (pp. 411-430).

shell of another genus of a well represented Upper Cretaceous to Tertiary family, the Adocidæ, and as being relatively the heaviest and most massive turtle shell yet discovered. Although originally a perfect fossil with suturally united carapace and plastron, only thirteen complete and five incomplete elements of the carapace, together with the hyo- and hypoplastron, have escaped the accidents of discovery and collection. Of the imperfect parts but four are diagnostic as to form, whence the recovered elements that are wholly determinative virtually number

1

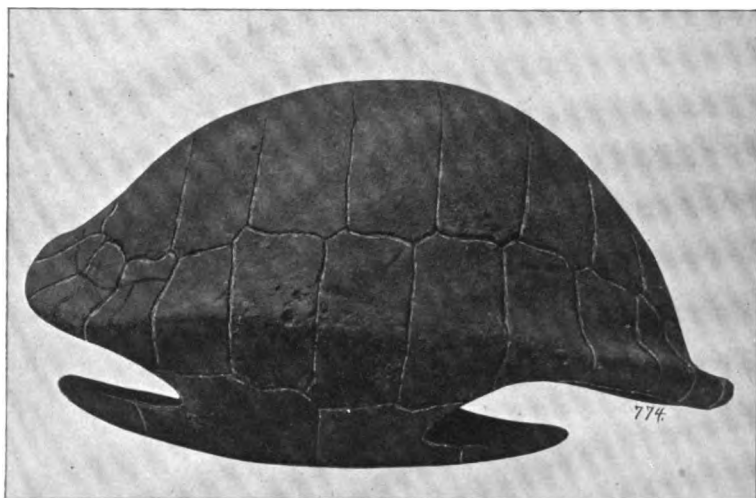


FIGURE 1.—*Agomphus tardus* Wieland (sp. nov.). Carapace and plastron of type specimen* with the missing portions restored in the estimated natural size and position. Actual length of carapace 33^{cm}. Elements present indicated in the succeeding figures 2-5.

but nineteen, or exactly one-third of the original fifty-seven elements of which the carapace and plastron was composed. These recovered elements of grayish to dark, marl green color, are however perfectly fossilized, uncrushed, disarticulated, and without crumbling or breaking of the sutural faces. Moreover they are by a rare and noteworthy chance so distributed as to clearly outline the missing elements and make possible a restoration by the Museum preparateur, Mr. Gibb, and the writer, which it is confidently believed by both will be found essen-

* Elements present: nuchal (incomplete), 2d and 5th neurals, left 1st and 2d pleurals, right 4th and 5th pleurals (incomplete), right 6th and 7th pleurals, left 2d marginal, left 5th and 6th marginals (incomplete), left 10th and 11th marginals, right 8th-11th marginals, the left hyo- and the right hypoplastron.

tially correct as to form and size whenever a complete individual of this species is fortunately discovered. A side view of the restoration is shown in figure 1, this being perhaps the best view; for it was not found possible to bring all the elements into an absolutely symmetrical position, although they are virtually so indicated in the supplementary drawings, figures 2-6.

2

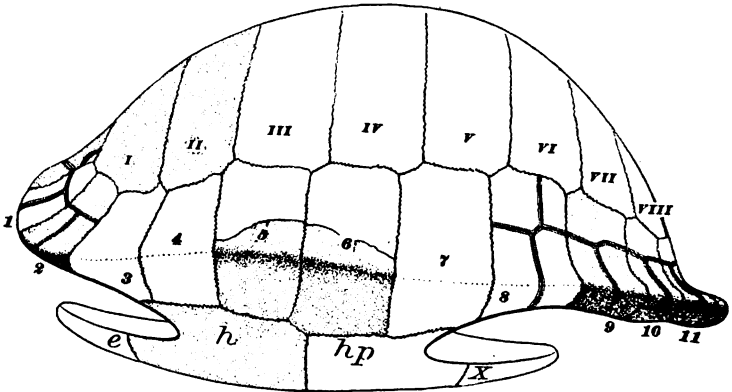


FIGURE 2.—*Agomphus tardus*. Left lateral view of the carapace of the type with elements present stippled (except 9th marginal). I-VIII and I-XI, the respective pleuralia and marginals; e, epiplastron; h, hyoplastron; hp, hypoplastron; x, xiphiplastron. [Actual length of specimen 33^{cm}.]

3

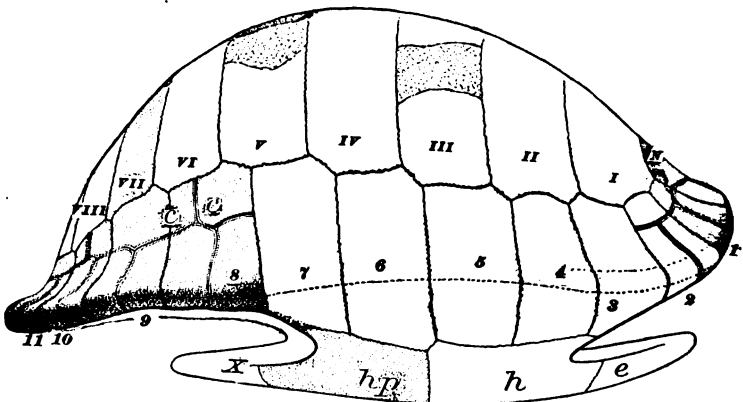


FIGURE 3.—*Agomphus tardus*. Right lateral view of carapace and plastron. Drawn from type with elements present stippled. N, nuchal; c, c, 3rd and 4th costalia. Other lettering as in the preceding figure.

As clearly shown in the figures, *A. tardus* was of robust oval form with marked depth over the inguinal region, and a distinct flanging of the nuchal region which gives the carapace a very symmetrical to ornate appearance. The rib capitulæ are diminutive. The medium-sized and heavy plastron without fontanelles is strongly interlocked by suture with the marginals, and the axillary buttress extends forward to the 3d, the inguinal buttress, back to the 8th marginal, as in *Adocus*.

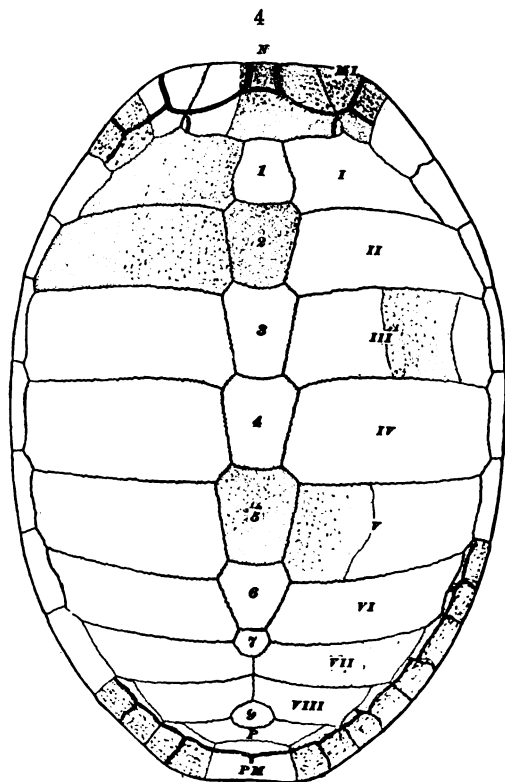


FIGURE 4.—*Agomphus tardus*. Dorsal view of the carapace. Drawn from the type with parts actually present stippled. *N*, nuchal; *MI*, 1st marginal. 1-7 and 9, the neuralia; *P*, pygal; *PM*, pygal marginal; I-VIII, the respective pleuralia.

The most curious single feature is the complete perforation of the first marginals by the costiform processes of the nuchal. (Cf. figure 6.) The outlines of the transverse sections of the several elements as shown in the supplementary figures 6 and 7, in connection with the measurements may render more

detailed description of the form of the individual elements unnecessary. These figures show in particular the enormous thickness of the elements of the plastron, which is especially heavy near to the hypo-xiphiplastral suture. There was, however, no trace of fusion with the pubes. The hornshields are for the greater part indicated by narrow sulci not accentuated in the nuchal region as in *Adocus*, with the inner

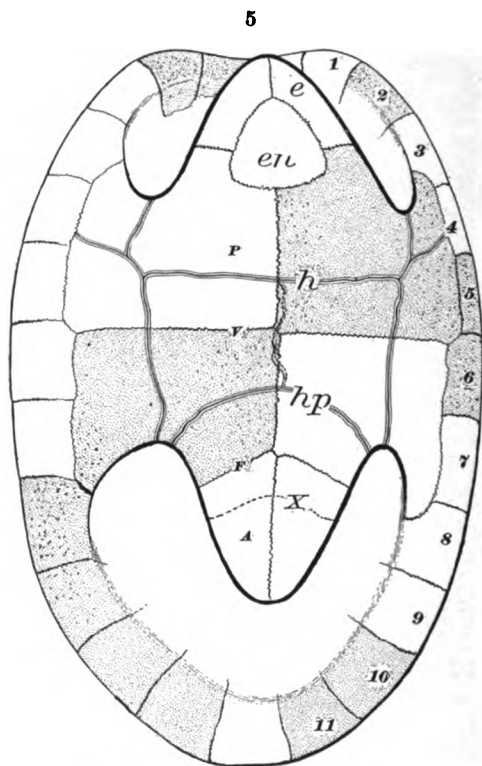


FIGURE 5.—*Agomphus tardus*. Plastral view drawn from the type. *P*, pectoral, *V*, ventral, *F*, femoral, and *A*, anal hornshields; *en*, entoplastron. Other letters and numbers as in figures 2 and 3.

borders of the marginalia, as is especially to be noted, not traversing the pleuralia as in that genus, but continuing below the pleuro-marginal sutures all round the carapace from the nuchal to the pygal region.

Specific Relationships.—The forms with which *Agomphus tardus* is to be compared are (1) *A. (Emys) firmus* (Leidy),

(2) *A. petrosus* Cope, (3) *A. turgidus* Cope, (4) *A. (Amphimys) oxy sternum* Cope, and (5) *Adocus (Pleurosternum) pectoralis* Cope,—all of which are either slightly or not illustrated and difficultly accessible or little known types, based on fragmentary materials of barely diagnostic value beyond family or generic limits. It appears, however, that in comparison with *Agomphus tardus* (sp. nov.), *A. (Emys) firmus* was a larger form with a shell relatively but not nearly so extremely heavy; that *A. turgidus* Cope (as further described from the Marsh Cotype No. 900), is a small turtle of about the same size as *A. tardus* with minor differences of form and horn-

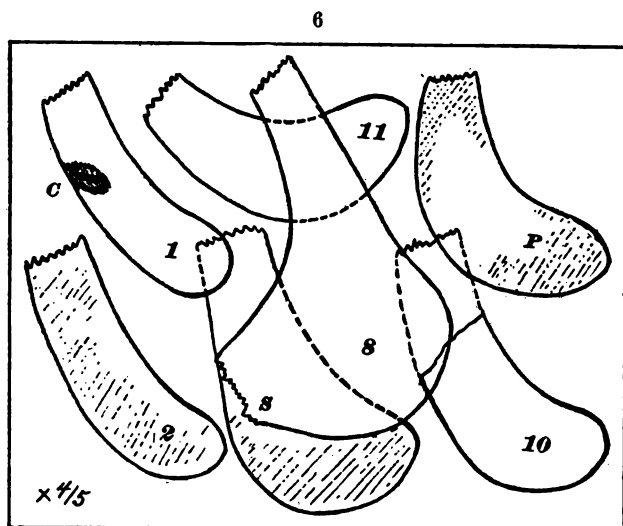


FIGURE 6.—*Agomphus tardus* (type). $\times \frac{4}{5}$. Outlines of the anterior sutural faces or transverse sections of the 1st, 2d, 8th, 10th, 11th and pygal marginals.—C, pit in anterior face of the right 1st marginal for the reception of the costiform process of the nuchal, which entirely perforates this marginal; S, sutural face for union of 8th marginal with the hypoplastron.

shield boundaries and far less robust plastron; that *A. petrosus* Cope had a steeper, less flanged or shovel-shaped nuchal region, with the hornshield sulci nearer the marginal border, and the plastron lighter; that *Adocus (Pleurosternum) pectoralis* had a much less massive plastron and narrower bridge than *A. tardus*; and that finally *A. (Amphimys) oxy sternum* from the Tertiary of Georgia is a fairly distinct species from all of the foregoing Agomphids.

Measurements of Agomphus tardus Type.

(Yale Museum Specimen No. 774. Skeletal elements uncrushed.)

THE CARAPACE.

Length on straight line	33· cm
Length over curvature	43·5 ±
Width (greatest, or over 4th neural)	23· ±
Distance over curvature (greatest)	38· ±
Projection beyond front end of plastron	1·5
Projection beyond anal end of plastron	7·

[Thickness of nuchal (anterior), 1·3^{cm}; (posterior), 7^{mm}; of the 2d neural 1·4^{cm}; of the 5th neural 1·5^{cm}. With the exception of the distal extremity of the second pleural, which reaches the great thickness of 2·2^{cm}, the pleurals are of much the same development throughout, their thickness being quite nearly indicated by that of the marginals given in transverse section.]

BONY PLATES OF CARAPACE.

	Length on marginal border of carapace.	Middle length from marginal border of carapace to pleurals.
Nuchal	5·2	5·3
1st marginal	4·	4·3
2d	4·2	4·6
3d	3·8	--
4th	3·8	--
5th	4·	--
6th	4·	--
7th	--	--
8th	--	--
9th	--	5·
10th	3·8	4·5
11th	4·2	4·
Marginalo-pygal	4·	3·

	Length (Antero-posterior).	Greatest width (lateral).
Nuchal	5·2	7·3
1st neural	--	--
2d "	4·	3·5
3d "	--	--
4th "	--	--
5th "	4·	3·6
6th "	--	--
7th "	--	--
8th "	(absent)	(absent)
9th "	--	--
Pygal	(3·)	--

(Lateral length 1st, 2d, and 7th pleurals 9·5^{cm}, 12^{cm}, and 8·7^{cm} respectively.)

THE PLASTRON.

	Greatest length on medium line.	Greatest width.
Epiplastron	—	—
Entoplastron	4.3	4.5
Hyo-plastron ..	6.0	10.
Hypoplastron	6.2	9.5
Xiphi-plastron	7. ±	3.3

(Greatest thickness of the hyoplastron measured on interior border 2.7^{cm}, of the hypoplastron 3.1^{cm}. Least width of hypoplastron measured across axillary border 5.6^{cm}, of the hypoplastron across the femoral border 5^{cm},—whence least width of bridge, 10.6^{cm}.)

7

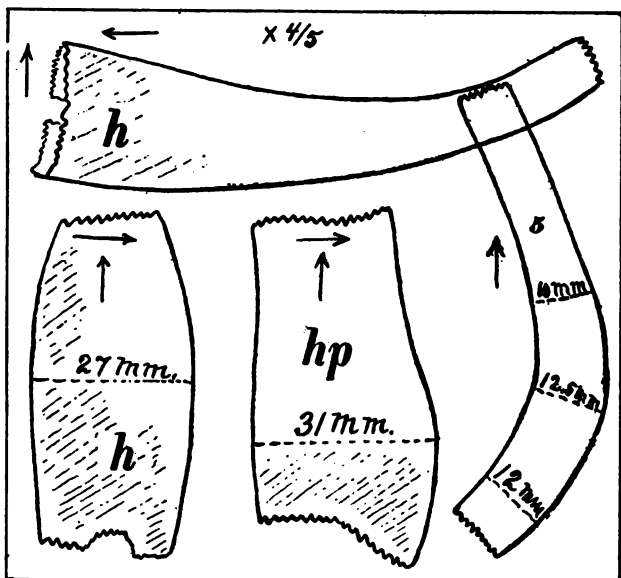


FIGURE 7.—*Agomphus tardus* (type). $\times \frac{4}{5}$. Outline of sutural faces (or transverse sections) of the hyoplastron, the hypoplastron, and the 5th marginal. *h*, *h*, posterior and internal sutural face of hypoplastron; *hp*, internal sutural face of hypoplastron, which placed tandem to *h* yields the median transverse section of the plastron, exclusive of the epi-, the ento- and xiphi-plastron; δ , anterior face, 5th marginal. The arrows orient to the vertical and median lines.

Agomphus masculinus Wieland (sp. nov.)—(Figure 8).

The beautifully fossilized plastron accompanied by various marginals, a nuchal and fragmentary pleurals of a smaller turtle than the preceding, received at the Yale Museum from the West Jersey Marl Co.'s pits, at Barnsboro, Gloucester

County, New Jersey, in April, 1872, and numbered 671 in the Marsh Collection, is here made the type of the new species *Agomphus masculinus*. This specimen undoubtedly pertains to

8

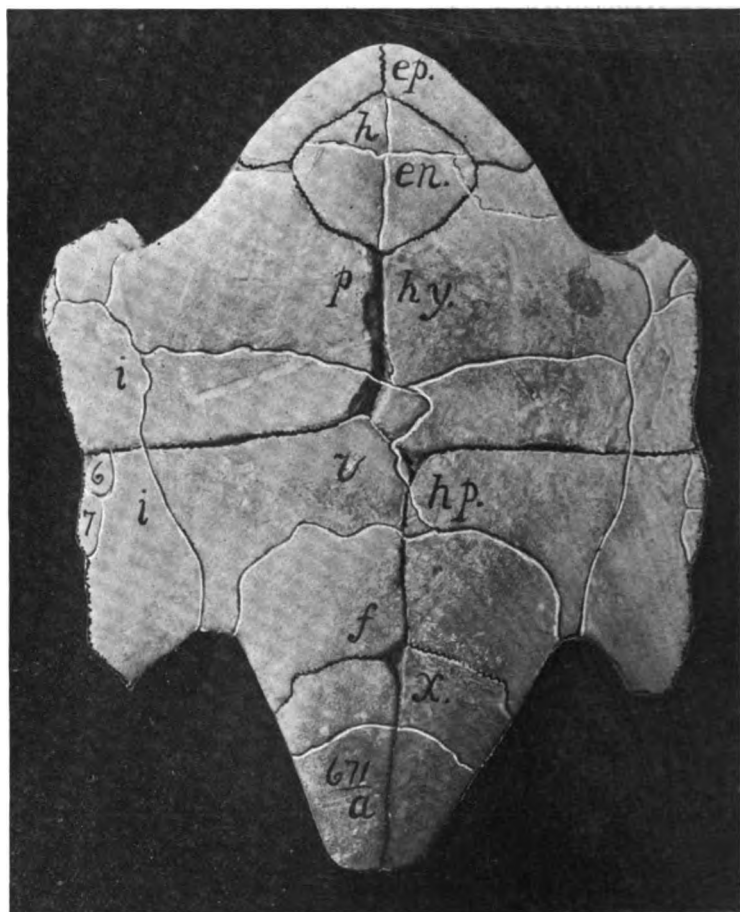


FIGURE 8.—*Agomphus masculinus* Wieland (sp. nov.). The plastron of the type specimen (No. 671, Marsh Collection), consisting in the entoplastron, hyoplastra, hypoplastra and right xiphiplastron complete (with the missing epiplastra and left xiphiplastron restored). $\times \frac{1}{4}$.

(1) Bone plates.—*ep*, epiplastron; *en*, entoplastron; *hy*, hyoplastron; *hp*, hypoplastron; *x*, xiphiplastron.

(2) Hornshields.—*h*, humeral (in part); *p*, pectoral; *v*, ventral; *f*, femoral; *a*, anal; *ii*, inframarginal region (above which the axillary inframarginal appears completely outlined); 6, 7, inner borders of the 6th and 7th marginal shields.

an originally complete fossil shell, but the several parts secured, although as numerous as in the preceding fossil, scarcely have the fortunate situation making possible a similar restoration.

The elements are all matrix-free, uncrushed and disarticulated, with the sutural faces all clearly outlined (save a small outer border portion of the left side of the plastron). Also the narrow to line-like hornshield sulci are all distinct in every instance. Unfortunately, but a single example of the present species is known with certainty.

The plastral features of *A. masculinus* as shown in figure 8 are more nearly similar to those of *A. tardus* than to those of any other known Agomphid. Specific identity is however clearly indicated by the slightly less robust form with relatively larger hypoplastra and ventral hornshields, and an entoplastron of sub-rhombic instead of sub-isosceles outline.

It is further to be observed that the doubly sigmoid antero-posterior curvature of the plastron is greater than in any other known species of *Agomphus*. Although this feature does not clearly appear in the photographic figure 8, it is so strongly accentuated in the fossil itself as to suggest that it is an individual peculiarity denoting an old male turtle, or perhaps better tortoise, whence the specific name.

In addition a new specific character is exhibited by the complete nuchal, and the third, eighth and tenth marginals accompanying the present plastron. These show that the marginal hornshields anterior to the eleventh did not overlap the pleuro-marginal sutures, and that the eleventh and twelfth did do so. As this peculiarity is not present in either *A. turgidus* or *A. tardus*, it in a sense unites *Agomphus* with *Adocus* since in *Adocus punctatus* at least, a similar hornshield overlap begins with the fifth marginal hornshield.

(a) *Measurements of the Plastron of Agomphus masculinus Type.*

Extreme length	17 cm
Extreme width	13
Length of bridge suture	10
Distance between the axillar and femoral borders	7.9
Length of the hyo-hyoplastral suture	5.5
Length of inner hyoplastral suture	4.
Length of inner hypoplastral suture	3.5
Length of inner xiphoplastral suture	4.5
Lateral width of entoplastron	3.6
Antero-posterior length entoplastron	3.4
Greatest thickness entoplastron	1.5
Greatest thickness hyoplastron	1.8
Greatest thickness hypoplastron	1.8
Greatest thickness xiphoplastron	1.6

Specimens 775 and 776.—(Figure 9).*

The characters of the plastron in the genus *Agomphus* are shown in still further specific detail by the complementary specimens 775 and 776 of the Marsh Collection, as represented in the retouched photographic figure 9. These two specimens, the parts of which are enumerated in the legend of figure 9, do not necessarily pertain to the same species. In fact specimen 776 indicates a turtle with a slightly heavier plastron and broader bridge than 775, although quite similar in all other comparable respects.

Specimen 776 probably belongs to *A. (Emys) turgidus*, although we note that it may perchance be separated from this form by the different outline of the humeral hornshields, and from *Adocus* (or *Agomphus*) *pectoralis* by the relatively larger plastral bridge. The bones, while unusually robust, do not reach the great thickness seen in both *A. tardus* and *A. masculinus*.

It is furthermore to be observed that specimen 775 is distinguished from both the species just named as well as from all other Adocidæ so far as known, by the series of accessory parallel growth lines of both the anterior and posterior sulci of the femoral hornshields. This peculiarity, as distinctly shown in figure 9, recalls the obverse condition of change from deep sulci in the nuchal region to narrow line-like sulci on all the rest of the carapace seen in *Adocus punctatus*. An imperfect accompanying hyoplastron however suggests proportions similar to those of *Adocus (Pleurosternum) pectoralis*, which we are fairly satisfied is an *Agomphus*. Were specimen 775 assigned to a new species, no one could say nay on the basis of the material now known, but to do so could only be defended, were no further examples likely to be yielded by the New Jersey Cretaceous.

While it is not therefore convenient to assign these specimens to any of the half dozen known types, and much less so to propose a new species for No. 775, it is held that whoever is fortunate enough to discover additional new specimens illustrating the doubtful points involved, will first be entitled to determine these specific values. For the present it is therefore only attempted so far as fairly practicable to make accessible the features of Agomphid structure. Nor do we consider that on last analysis there is any essential difference between this structural study and the more purely taxonomic point of view.

* No. 775 is from the Cream Ridge Marl Co.'s pits, Hornerstown, Monmouth Co., New Jersey. It was received at the Yale Museum in April, 1871. No. 776 is doubtless from the same locality, but there is a discrepancy in the Museum record, so that it is not positively known where this fossil is from.

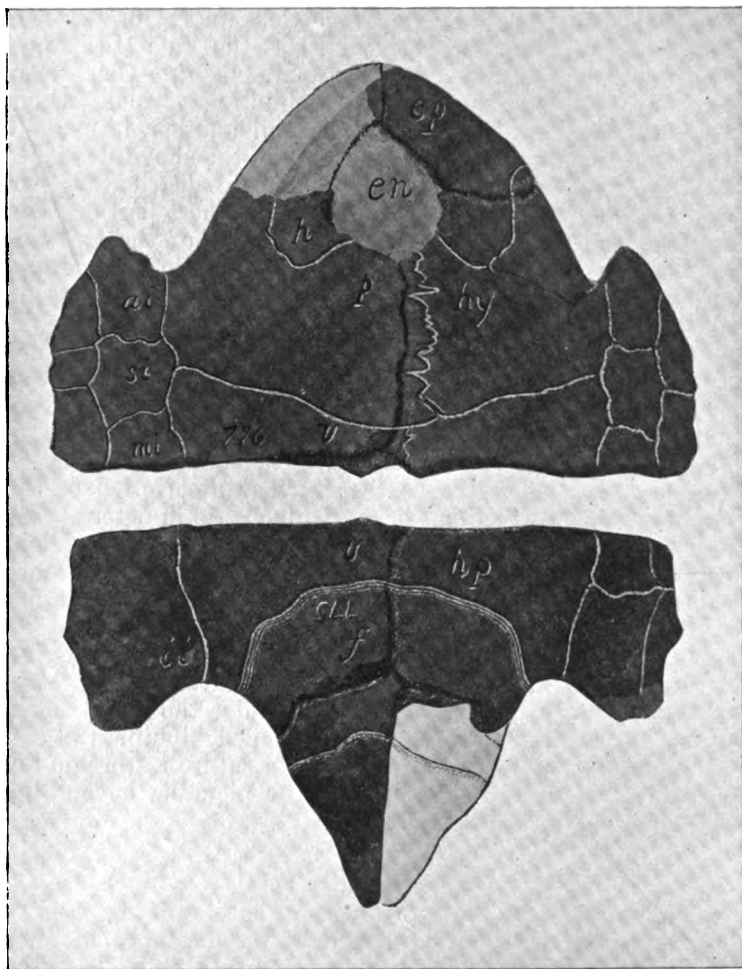


FIGURE 9.—*Agomphus*. Two complementary specimens illustrating plastral structure. No. 776, consisting in the hyoplastra and epiplastra, may be doubtfully referred to *A. turgidus*. No. 775, consisting in the hypoplastra and xiphiplastron, is of more uncertain specific reference. Both the specimens are shown exactly $\frac{1}{2}$ natural size.

(1) Bone plates.—*ep*, epiplastra; *en*, entoplastra; *hy*, hyoplastra; *hp*, hypoplastra; (xiphiplastron not lettered).

(2) Hornshields.—*h*, humeral (in part); *p*, pectoral; *v*, ventral; *f*, femoral; *ai*, axillary—*si*, sub-axillary—*mi*, mesial—and *ii*, inguinal inframarginalia; (anal hornshield not lettered).

Agomphus turgidus (Cotype).

It is of interest to further note that the specimen (number 900) from the Cream Ridge Marl Co.'s pits Hornerstown, Monmouth Co., New Jersey, received at the Yale Museum in 1869, is clearly a second specimen of *A. turgidus* Cope, from the same locality as the type, and exhibiting various further structural features. Indeed here is still another instance in which more elements are present than in the above described *A. tardus*, although without the fortunate distribution permitting a restoration as in that specimen. These portions are: the entoplastron and both *hyoplastra* (that of the left side articulating with the nearly complete 3d marginal), the right 5th–11th marginals (the 6th and 7th having the superior and inferior borders broken away), the pygal marginal and the lower halves of the left 4th, 6th and 7th marginalia; also the second, a 6th or 7th neural, and the third and fourth neuralia complete with the proximal ends of the left 3d–5th and the right 4th pleuralia attached.

The specific characters of *A. turgidus* have already been commented on indirectly, so that further description of the present specimen which has been of much use in determining the preceding new species, is scarcely required. The original fossil shell was doubtless complete, and had but a few more fortunately situated elements been recovered a restoration could be made.

A. turgidus did not have as massive a shell as *A. tardus*, but presents all the characteristic generic features distinguishing *Agomphus* from *Adocus*; in particular the heavy shell, the sharp to acuminate rather than rounded xiphiplastral end of the plastron, and the marginalo-costal suture resting on the marginals, instead of rising up onto the pleuralia beyond the third marginal hornshield.

Synopsis of the Characters of Agomphus.

The description of the foregoing new species of *Agomphus*, *A. tardus* and *A. masculinus*, and of the plastra of more or less doubtful specific identity numbered 775 and 776 in the Marsh collections, together with a topotype of *A. turgidus*, finally acquaints us with the shell structure of this interesting Upper Cretaceous genus as follows:

Carapace.—Medium sized to small, of elliptical outline, considerable depth, and with thicker walls in some species than in any other known Testudinates. Composed of 49 bony plates (one more or less, depending on the presence or absence of 7th and 8th neurals), and without fontanelles. Hornshield sulci small and line-like to indistinct.

(a) *Bony plates*.—Marginals, 11 pairs, very heavy; nuchal, large, of sub-pentagonal outline, without a nether process, but with costiform processes sometimes perforating the entire 1st marginals (*A. tardus*); neural series with but seven or eight members—the 9th or post neural being present with suppression of the 7th, or both 7th and 8th; pygal single as in *Adocus*; pleuralia very heavy with medium to slight development of the rib capitulæ.

(b) *Hornshields*.—A medium-sized nuchal and twelve pairs of marginals with the inner or marginalo-costal suture not rising onto the pleurals, as in *Adocus*, but traversing the marginal plates throughout (except in the single species *A. masculinus*, where the penult and final or pygal shields respectively overlap the 8th pleural and pygal plate.

Plastron.—Of medium size, without fontanelles and very heavy with the strong bridge suture extending from the posterior end of the 3d to the anterior end of the 8th marginal. Entoplastron large, of sub-isosceles triangular to rhombic outline. Epiplastral border rounded; anal region acuminate in every known species—not rounded as in *Adocus*.

Agomphus is held to be distinct from the earlier proposed genus *Adocus* mainly because of the position of the marginalo-costal suture on the marginals, the very characteristic form of the plastron, and the enormous thickness of shell. Although some of the imperfectly known species may prove to intervene and bridge these gaps—not large when taken singly,—it appears at present that they uniformly separate an Agomphid series of closely related, mostly small turtles ranging from the Upper Cretaceous into the Eocene. Therefore, as both *Adocus* and *Agomphus* are numerous in species, it would seem to be much the better policy to retain the latter genus so long as not definitely proven to merge into the former. The species respectively assigned to these two closely related genera of the Adocidæ therefore are:

1. *Adocus (Emys) beatus* (Leidy) Cope.
2. " *agilis* Cope.
3. " *pravus* (Leidy) Cope.
4. " *syntheticus* Cope.
5. " *punctatus* Marsh.
6. *Agomphus (Emys) turgidus* (Leidy) Cope.
7. " " *firmus* (Leidy) Cope.
8. " (*Amphiemys*) *oxysternum* (Cope) Hay.
9. " *petrosus* Cope.
10. " (*Adocus*) *pectoralis* (Cope) Wieland.
11. " *tardus* Wieland.
12. " *masculinus* Wieland.

From this numerous assemblage of species we naturally come to ask how turtles with such thick shells as the Agomphids, the more naturally ascribed to land forms, came to be so intimately associated with *Osteopygis*, *Lytoloma*, and the various other semi-marine to marine turtles and other forms which teem in all the *Agomphus* localities in the Upper Cretaceous marl beds of New Jersey. Being mostly small turtles the heavy specialized shells would mainly serve as a protection from the other larger and more powerful reptiles, which swarmed along and into the bays and estuaries of the New Jersey Cretaceous shore line, so that a salt water littoral habitat is not precluded. But while no specimens of the Marsh or other collections illustrating limb or cranial structure have yet been referred to *Agomphus*, it would seem that at least some of the species of the genus dwelt back from the shore line along the streams, on the more or less sandy river, ox-bow, or delta banks, and doubtless in the vast numbers paralleling the Orinocan *Podocnemis*, the easy prey of the jaguar, and once far more abundant on lower river courses than now. From such locations many shells might be carried forward to the shore front in flood time or in the course of estuarial change. Also, if congregating in any considerable numbers on the more nearly forest-free river banks, or on dune slopes, at egg-laying time, many individuals might then be either preyed on by other animals, or swept shoreward. It is a fact of some slight bearing on such a conjecture that while the Adocidæ are much more numerous than the other Testudinates of the marl beds, nearly all the limb bones recovered pertain to the semi-marine to marine Osteopygid and Lytoloman series. Moreover the abundance of the fossils of the marl beds is probably not generally understood, since almost no specimens have been secured in the past twenty-five years. Only a very few per cent of the specimens uncovered in the marl pits, when excavation was actively carried on thirty years ago, ever made their way into the museums; and these were all from restricted areas, although these fossils were for the greater part abundant everywhere in the several fossiliferous horizons of the entire New Jersey marl belt.

Yale Museum, New Haven, Conn.

ART. XLV.—*The Cambro-Ordovician Limestones of the Middle Portion of the Valley of Virginia*; by H. D. CAMPBELL.

NEITHER the Knox dolomite nor the Shenandoah limestone, if used as the name of a geologic formation, should be made to include all of the Cambrian and Ordovician limestones of the Valley of Virginia from Tennessee to Maryland.

M. R. Campbell* makes the Shenandoah limestone of southwest Virginia comprise not only the Knox dolomite but at least 1500 feet of Cambrian strata beneath it. He also describes two formations of limestone above the Shenandoah and recognizes 500 feet of subjacent variegated shale and impure limestone.

At the border between Tennessee and Virginia† he makes the Shenandoah limestone include not only the Knox dolomite but five other formations, remarking that the six merge into one formation which prevails along the eastern side of the Appalachian valley at least as far as Pennsylvania.

It is not the purpose of this article to discuss the correlation of the Knox dolomite and the Shenandoah limestone, which can be satisfactorily accomplished only after several additional sections across the valley of Virginia have been described in detail and the fossils from fixed horizons have been compared.

This introduction is offered as an explanation for using the following entirely new names for the formations recognizable in the limestones of the portion of the Appalachian valley near Lexington and the Natural Bridge, Virginia.

Section of the Valley Limestones near Lexington, Virginia.

Period.	Name of formation.	Thickness in feet.
Ordovician	Liberty Hall limestone	1000 ±
	Murat limestone	100-150
	Natural Bridge limestone	3500 +
Cambrian	Buena Vista shale	600-900
	Sherwood limestone	1600-1800

Sherwood limestone.—In the bluff of James River at Sherwood, Va. and for more than twelve miles to the southwest, the lower part of this formation consists of several hundred feet of white crystalline dolomite. This dolomite is overlaid by heavy beds of light blue and gray magnesian limestone with occasional beds of shale and shaly limestone. It was just beneath or at the very base of the Sherwood limestone that

* U. S. Geol. Surv., Geol. Atlas of U. S., Folio No. 26, 1896.

† Ibid., Folio No. 59.

C. D. Walcott* found Lower Cambrian fossils. The formation is superjacent to the quartzites and shales of the Balcony Falls section.

Buena Vista shale.—Bright variegated shale is conspicuous in the bluffs of James River between Sherwood and Buchanan, and along the road between Sherwood and Natural Bridge. Red bands predominate, but green, yellow, and brown colors are common. Mottled blue limestone beds alternate with the shale in the lower part, and it passes by a succession of shale and limestone beds into the superjacent limestone. In this formation C. D. Walcott† found a *Ptychoparia* closely related to species from the Middle Cambrian beds of Tennessee. The formation is from 600 to 900 feet thick. It receives its name from Buena Vista, Va., where it is well developed.

Natural Bridge limestone.—The formation consists principally of heavy-bedded gray and light blue magnesian limestones with thin siliceous laminæ as a conspicuous feature, especially upon weathered surfaces. Beds of white and pinkish dolomite occur now and then. Calcareous sandstone strata from a few inches to eight feet thick are occasionally prominent. Black chert occurs in nodules more or less throughout the formation, but heavy beds of chert are usually very conspicuous near the top. Specimens of *Lingulepis* and *Obolus* were discovered by C. D. Walcott in this formation two miles below Buffalo Mills on Buffalo Creek in June 1898, thus establishing by fossils the age of part of this limestone as Cambrian. Fossils from 300 or 400 feet below the top of this formation make the age of its upper beds Beekmantown (Calcareous).‡

On account of the difficulty of determining the geologic structure in this section, the total thickness of the formation has not been accurately determined, but measurements which were made in a continuous series where there was no indication of folding or faulting indicate a thickness of over 3500 feet. The Natural Bridge and its canyon display part of this limestone, and hence the name.

Murat limestone.—Superjacent to the heavy chert beds of the Natural Bridge limestone occurs a massive gray crystalline limestone containing bryozoa and other fossils in abundance. About 125 feet of it are well exposed along Buffalo Creek at Murat, Va., whence the formation takes its name. Its lower portion often contains chert nodules. The deep red clay soil resulting from the Murat limestone is conspicuous in contrast with the gray cherty soil from the top of the Natural Bridge formation.

* This Journal, July 1892, p. 53.

† Ibid., p. 52.

‡ R. S. Bassler, Bull. U. S. Geol. Surv. No. 243, 1905, p. 315.

Liberty Hall limestone.—In describing a section through this region in 1879, J. L. Campbell* used the name Lexington limestone for this formation, but inasmuch as the same name is given to certain Silurian rocks in Kentucky,† it has been rechristened Liberty Hall limestone from the name of an old historic ruin which is constructed on and of this rock, and which has been standing for more than a century and is as well known in this region as Lexington itself.

The Liberty Hall limestone is usually a succession of rather evenly banded beds of fine-grained, dark blue limestone and darker, more argillaceous limestone which weathers shaly. As we ascend into the formation calcareous shale predominates and limestone beds are less frequent. In this region the formation has been much fractured and folded, and sometimes appears massive with innumerable veins of infiltration of calcite filling the crevices. Again it appears shaly after long exposure to weather. Brachiopods and trilobites of Mohawkian age are especially abundant in the lower beds. From the top of the Murat through the limestone and calcareous shale, so long as it carries conspicuous limestone beds, the Liberty Hall limestone is about 1000 feet thick. Then follows about 600 feet of shale and slabby sandstone to the bottom of the first bed of quartzite above the Valley limestones. The thick beds of shale above the limestones, both northeast and southwest of the section here considered, give rise to another problem of correlation.

Washington and Lee University,
Lexington, Virginia, October 31, 1905.

* This Journal, xviii, 1879, p. 29.

† U. S. Geol. Surv. Geol. Atlas of U. S., Folio No. 46, 1898.

ART. XLVI.—*Relations of Ions and Nuclei in Dust-free Air;*
by CARL BARUS.

1. In the following table I shall give typical results of the nucleation computed from the coronas observed in a glass fog chamber, in the presence or absence of external radiation, when the saturated dust-free air contained is suddenly cooled by partial exhaustion of successively increasing magnitude. The amount of exhaustion (with which the supersaturation goes in parallel) may be conveniently specified in terms of the drop in pressure, δp , between the outside and the inside of the given moderately efficient fog-chamber. Since the barometer was nearly normal, the corresponding volume increase, etc., may be readily derived.

TABLE I.—Typical results of the ionized and colloidal nucleation of dust-free air, energized (or not) by weak and strong radiation. Fog chamber about 50^{cm} long, 15^{cm} in diameter; walls of glass 3^{cm} thick, ends 1^{cm} thick. Piping of one inch gas pipe. Barometer about normal. *D*, distance between walls of fog chamber and anticathode or sealed aluminum tube with weak radium.

X-rays		X-rays		Radium		X-rays		X-rays	
<i>D</i> =∞	from end	<i>D</i> =600 ^{cm}	from end	<i>D</i> =0 ^{cm}	from side	<i>D</i> =100 ^{cm}	from end	<i>D</i> =50 ^{cm}	from side
δp	$n \times 10^{-3}$	δp	$n \times 10^{-3}$	δp	$n \times 10^{-3}$	δp	$n \times 10^{-3}$	δp	$n \times 10^{-3}$
21	0	19	? 0	19	2	18	0	18	0
23	5	20	2	20	2	19	1	19	2
25	1.7	21	8	21	10	20	20	20	*10
27	5	22	20	22	28	21	37	21	*28
28	18	23	28	23	38	22	50	22	57
29	45	24	33	24	45	24	75	24	93
30	59	26	36	25	50	26	95	25	110
32	73	28	37	26	52	28	110	27	133
34	87	30	39	28	53	30	124	29	145
36	100	34	41	30	55	35	135	32	155
--	---	--	--	35	56	--	---	35	160

In computing the (fleeting) nucleation one is left in doubt whether the nuclei (ions) are restored to the air more quickly than they can be removed by exhaustion; or whether the reverse is true. I have assumed the former to be the case and call this nucleation (number per cubic cm.) *n*. If the nuclei are removed more quickly than they are reproduced, it will be necessary to multiply *n* by the corresponding volume increase, and I shall call this value *N*. In the present experiments† *N*

* Probably reduced by the presence of persistent nuclei in small number.

† At high values of δp both *n* and *N* become untrustworthy as absolute values; but they suffice very well to indicate the relations.

is usually much larger than n . In the cases of persistent nucleation due to the X-rays or other causes, N is obviously to be taken; but here from the low values of δp which suffice for condensation, the difference is not so important.

2. To vary the intensity of radiation, the anti-cathode of the X-ray tube or the radium tube (of thin aluminum, hermetically sealed, holding 10 mg. of weak radium —10,000 \times — within), is placed at a distance, D , from the outside of the fog-chamber. This was a horizontal cylinder of glass, 50^{cm} long and 15^{cm} in diameter, with the end toward the bulb 1^{cm} thick and the side wall 3^{cm} thick. When D is measured from the end, persistent nucleation is not usually producible* because of the thickness of the glass to be penetrated. When D is measured from the sides, however, persistent nucleation just begins at $D = 50^{\text{cm}}$ and increases at a rapidly accelerated rate for smaller distances. Hence the ionization corresponding to $D = 50^{\text{cm}}$ is a transitional value at which fleeting nuclei or ions merge into persistent nuclei.

3. If the data are constructed graphically, it appears that all the curves are eventually intersected by the curve for dust-free non-energized air. In the latter we may recognize a region of ions (say from $\delta p = 21^{\text{cm}}$ to 27^{cm}) and a region of colloidal nuclei for larger values of δp ; but the whole phenomenon is continuous. The effect of radiation as seen in the other curves is therefore to decrease the efficient nucleation of

TABLE II.—Persistent (large) nuclei (N , number per cm^3) produced by intense X-radiation, in dust-free air. $\delta p = 18^{\text{cm}}$, being decidedly below the fog-limit. D measured from side of glass fog chamber (wall 3^{cm} thick) to anticathode. Aluminum screen inserted.

$D =$	12	20	30	40	50 ^{cm}
$N \times 10^{-3} =$	140	56	10	1	1

dust-free air more noticeably when the radiation is weaker and the supersaturation higher. These results may be tried directly for instance, with the radium tube at different distances, D ; for a fixed pressure difference, δp . Thus at $\delta p = 41^{\text{cm}}$ the nucleation passes through a minimum at $D = 25^{\text{cm}}$ when D increases from 0 to 50^{cm} . The effect of radiation is then virtually an aggregation of the colloidal nuclei of dust-free air. If the effect of ionization were merely to mask the presence of the smaller colloidal nuclei, the same effect should occur at intense ionization. Here, however, nuclei larger as well as indefinitely smaller than the mean ionic gradation are produced like the latter in continually greater numbers as the radiation increases. The case is rather one in which relatively

* I have since succeeded in producing persistent nucleation through thin tin plate.

supersaturations and the asymptotes (or maxima) are in every case reached and much higher in value. The range of supersaturation within which the condensations begin and are nearly completed is reduced so that the curves are usually steeper. In case of the new curve for non-energized air (and to the same extent in the others) the relative absence of nuclei in the region of ions is a distinguishing peculiarity. Investigated by the coronal methods, the curves rise, as it were, abruptly from the abscissa, and there is a rise of fog limit.

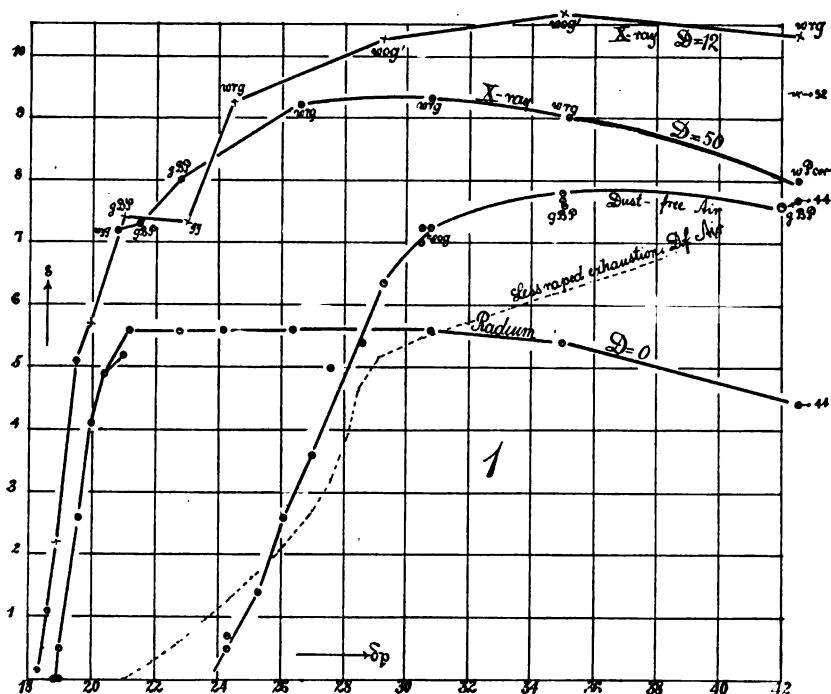


FIG. 1.—Charts for Table III, showing the coronal apertures (angular diameter being $s/30$) in cases of different supersaturation (pressure drop on exhaustion δp) in cases of non-energized dust-free air, and of dust-free air energized by radium and the X-rays from different distances, D . The dotted curve corresponds to less rapid exhaustion (Table I). Its intersection with the corresponding curve drawn in full should be noticed. It indicates the presence of a group of larger nuclei present in the former case and absent in the latter.

5. In connection with the present data, different suggestions made in the earlier paper and diverging from the more usual explanations, may be recalled: The effect of radiation if not too strong, has been shown to be virtually an aggregation of the colloidal nuclei of dust-free air. It seems probable

that the ions or fleeting nuclei are such loose aggregates built up out of colloidal nuclei, because evidence of the presence of colloidal nuclei absent at the low ionizations (exposure to weak radiation) is manifest at the high ionizations (exposure to intense radiation). If the radiation is very strong all sizes are represented, showing that the aggregates are virtually built up out of continually smaller colloidal nuclei probably closely approaching the molecular sizes, while at the same

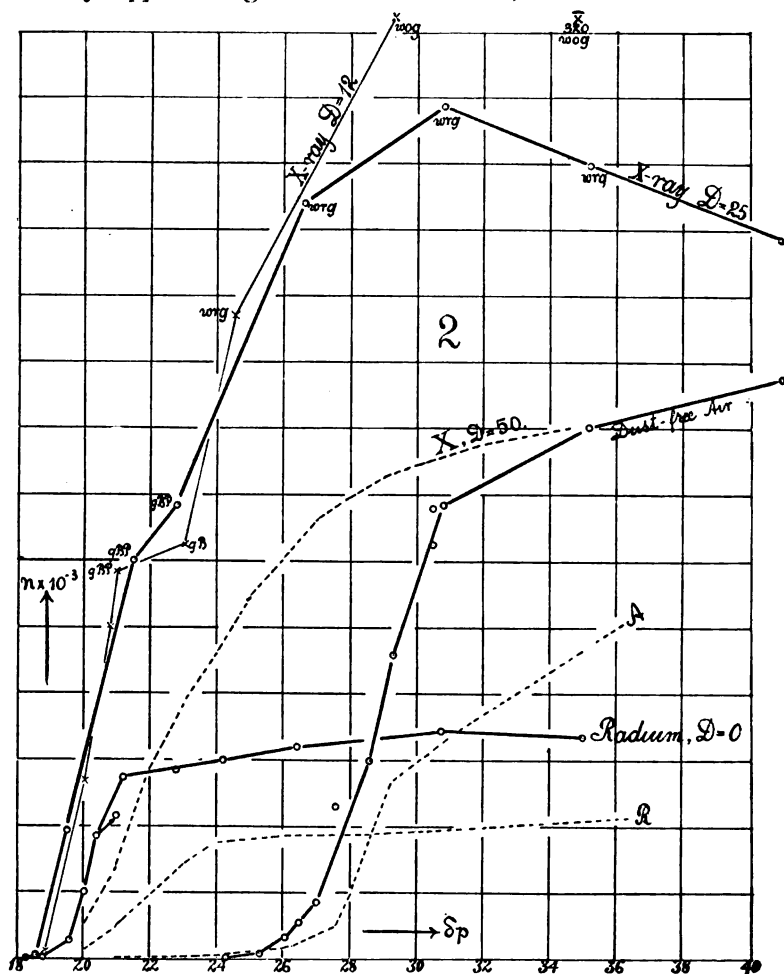


FIG. 2.—Charts for Table III showing the nucleation n in terms of the supersaturation (pressure drop δp), for dust-free non-energized air, and for dust-free air energized by radium ($10,000 \times$, 10 mg.) from different distances D . The dotted curves show the corresponding cases (Dust-free air, A ; Radium, R ; X-rays, X) for less rapid exhaustion (Table I). The vertical spaces represent 20,000 nuclei each.

time the existing nuclei are further aggregated into larger systems.

Within the fog-chamber it is probable that the radiations whether undulatory or corpuscular, is at any point the same in all directions, for the nuclei in any given case are largely produced by secondary radiation.

Hence it follows, qualitatively at least, that the inside of the fog-chamber is an ideal Lesage medium. One may argue, therefore, that a corresponding tendency for the preëxisting colloidal nuclei of dust-free air to aggregate into ions or larger bodies, should be manifest. Again the ions, conditioned by the presence of radiation, must fall apart when the radiation is withdrawn, and this is the case. One may infer also that the nucleating effect produced by negative corpuscles would be different from that corresponding to the positive residuals.

Let the kinetic ionization pressure be supposed to increase as the square of the velocity of the corpuscles and as their density of distribution; then if the ionization becomes very intense it is possible that the pressure becomes strong enough to produce permanent union of the loose aggregates, or that the fleeting nuclei eventually become persistent, as is the case.

If the ionized field is intensely produced by corpuscles issuing from within the body itself, as for instance, in combustion, or ignition, etc., one may expect that large nuclei as well as fleeting nuclei should simultaneously appear; or that nucleation, passing through a transitional stage from fleeting to persistent as the electrification is more intense, should be the invariable concomitant of ionization. It is probable that the expulsion of corpuscles takes place whenever persistent nuclei are produced. Thus in the case of the X-rays, the generation of persistent nuclei occurs at an accelerated rate with time for a fixed radiation. If the radiation is cut off, nuclei are spontaneously generated (secondary generation) for some time after.

Arguments to the same effect would follow for light pressure for wave lengths small enough to be easily scattered. Thus persistent and fleeting nuclei as a simple continuous phenomenon are produced by the X-rays (Table II), in the manner identical with the case of ultra-violet light. Similarly nuclei grow large in size as the ignition, the potential differences, etc., are larger.

Finally, although the colloidal nucleation of dust-free air may be conceived to be aggregated both by undulatory and by corpuscular pressure, it is only in the latter case that the nuclei can be influenced by an electric field because the corpuscles are themselves actuated. This distinction in fact exists between nuclei otherwise quite identical fleeting or persistent, but produced in one case by ultra-violet light and in the other by the X-rays or the action of radium.

Brown University, Providence, R. I.

ART. XLVII.—*Additional Notes upon the Estimation of Cadmium by Means of the Rotating Cathode, and Summary;*
by CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxli.]

I. *The Behavior of Cadmium Nitrate.*

SINCE cadmium is not readily precipitated by the electric current from solutions containing even small amounts of free nitrate acid, it was to be expected that cadmium nitrate would prove to be little fitted for estimation by electrolysis, since the action of the current would produce nitric acid. This, in general, was the result of my experiments upon the estimation of cadmium in the form of the nitrate upon the rotating cathode. The deposits obtained from solutions containing sulphuric acid, the phosphates, pyrophosphates, urea or formaldehyde, were satisfactory, but the time necessary for complete deposition is so prolonged that these solutions are comparatively valueless for the estimation of cadmium taken as the nitrate, since it would be easier and more trustworthy to transform the salt to the sulphate by evaporation with sulphuric acid before electrolyzing. With solutions containing acetic acid the metal was not precipitated, except in a narrow ring at the surface of the liquid. The behavior of solutions containing formic acid, tartaric acid, acetaldehyde and formaldehyde was similar, but less pronounced. The only solution from which I was able to obtain satisfactory results in the estimation of cadmium nitrate was a solution containing potassium cyanide. This solution was prepared by adding to the solution of cadmium nitrate, which had been standardized by the precipitation and ignition of the carbonate, the desired amount of sodium hydroxide, and then redissolving the precipitated hydroxide in an excess of potassium cyanide. The time needed for complete deposition is somewhat longer than that required where the chloride and sulphate of cadmium were taken, but the deposit was bright and very satisfactory. Care must be used to avoid the use of too large an amount of potassium cyanide. The following table shows the results obtained :

No.	Cd. grm.	KCN. grm.	NaOH. grm.	Cur't = amp.	N.D100. amp.	E.M.F. vts.	Time. min.	Tot. vol. cm ³ .	Cd. fd. grm.	Error. grm.
1.	0.0920	1.5	0.5	4.0	12.0	7.8	45	60	0.0933	+0.0013
2.	0.0920	1.0	0.5	3.0	9.0	7.6	35	60	0.0924	+0.0004
3.	0.1073	0.7	0.5	2.5	7.5	7.7	50	60	0.1072	-0.0001

II. *The Behavior of Solutions containing Free Nitric Acid.*

If free nitric acid be added to a solution containing a salt of cadmium, the precipitation of the cadmium by the electric cur-

rent will be retarded, and even prevented altogether if the nitric acid be present in sufficient amount. Upon this behavior have been based methods for the separation of copper, bismuth and mercury from cadmium.* Tests were made by me to determine the amount of free nitric acid necessary to prevent deposition of the cadmium, and it was found that 2^{cm}³ of nitric acid of 1:4 dilution in 50^{cm}³ of solution (approximately 1 per cent of free acid) will absolutely prevent the precipitation of the cadmium upon the cathode (current, 3 amperes; E.M.F., 7.5 volts). If less nitric acid was used, traces of cadmium were deposited upon the cathode.

Summary of Results obtained in the Estimation of Cadmium by means of the Rotating Cathode.

The results of the work described in this and the previous papers upon the estimation of cadmium by means of the rotating cathode may be briefly summarized as follows: Under the conditions used, cadmium taken in the form of the sulphate may be very accurately and satisfactorily estimated by deposition from solutions containing sulphuric acid, sodium acetate and acetic acid, or potassium cyanide; but little less satisfactorily from solutions containing urea, formaldehyde or acetaldehyde; and also with proper precautions, from solutions containing pyrophosphates, phosphates, tartaric acid or formic acid. From solutions containing oxalates or oxalic acid, ammonium tartrate, or potassium formate, however, I was unable to obtain satisfactory deposits. When taken as the chloride, cadmium does not permit such a wide range of conditions. Nevertheless, from solutions of the chloride containing sulphuric acid or potassium cyanide, or the pyrophosphates, the metal is deposited in a form comparable with that obtained when cadmium sulphate is taken. Solutions of the chloride of cadmium to which is added hydrogen disodic phosphate gave less desirable results; while solutions containing urea, formaldehyde or acetaldehyde gave deposits free from sponginess only after careful regulation of the conditions. In addition to the solutions containing the oxalates, oxalic acid, the formates and the tartrates, negative results were given in the case of the chloride by solutions containing the acetates, formic acid, and tartaric acid. The nitrate of cadmium is ill-fitted for electrolytic estimation, the cyanide solution being the only one from which satisfactory results were obtained. From solutions containing one per cent or more of free nitric acid, the cadmium is not deposited by the current.

* Edgar F. Smith, *Am. Ch. J.* ii, 42 (1880); Smith and Mayer, *J. Ch. Soc.*, lxiv, ii, 496 (1893); Kammerer, *J., Am. Ch. Soc.*, xxv, 94 (1903); Rüdorff, *Z. angew. Ch.* (1894), 388.

ART. XLVIII.—*The Estimation of Cadmium as the Oxide*;
by CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxlii.]

CADMIUM may be simply and accurately estimated by converting the carbonate to the oxide by ignition. The oxide of cadmium may be subjected to very intense heat without loss from volatilization; but in the presence of any carbonaceous matter it is very easily reduced to the metal, which is quite volatile at high temperatures. Consequently, this method has always been subject to more or less change of error where paper filters have been used. The usual course has been to wash thoroughly and then dry the precipitated carbonate, which is then removed as completely as possible from the filter: the latter then being burned separately. Even here there has always been a very appreciable loss, to avoid which various more or less complicated modes of treatment have been offered. As a type of these, we may take that of Max Muspratt,* who, after noting that high results were given by the ignition of the nitrate formed by dissolving the precipitated carbonate in nitric acid on account of included sulphate, proceeded as follows: The precipitated carbonate was washed and dried, and as completely as possible scraped free from the filter paper, and then converted to the oxide by gentle ignition. This carbonate was entirely free from sulphate. The filter paper was treated with nitric acid and the resulting solution and rinsings brought into a large porcelain crucible and evaporated to dryness. The dry nitrate was gently heated and the weight of the oxide obtained added to that of the mass of the precipitate. Even after this tedious procedure, Muspratt is obliged to suggest that the results will be more satisfactory if the oxide obtained by the ignition of the paper and the residues upon it be calculated as Cd_2O rather than CdO . Evidently the method would give satisfactory results if this reducing action of the filter could be avoided, and in former papers from this laboratory,† it has been shown that this may be accomplished by the use of asbestos filters in a Gooch crucible. There is then no danger of loss from reduction, and the carbonate method is simplified and placed among the good analytical methods. Recently, however, Miller and Page‡ have found that “the carbonate method is the most troublesome and the least satisfactory,” but these investigators did not use the asbestos filter.

* J. Soc. Ch. Ind.; xiii, 211 (1894).

† Browning, this Journal (3), xli, 280 (1893); Browning and Jones, *ibid.* (4), ii, 269 (1896).

‡ Ch. News, lxxxiv, 312 (1901).

The work of the writer upon the carbonate method fully substantiates the previous work from this laboratory. For the determinations given, a solution of cadmium sulphate was used, whose standard was accurately given by the average of a large number of closely agreeing electrolytic determinations. Portions of this solution were accurately measured from a burette and diluted to 300^{cm}³ with hot water. A 10 per cent solution of potassium carbonate was then added, drop by drop, with constant stirring until no further precipitation took place. The whole was then boiled for about fifteen minutes, when the precipitate became granular and quickly settled. It was then filtered upon an asbestos mat in a Gooch crucible, which had previously been ignited and weighed, and was then carefully washed with hot water. In several cases, washing by decantation was used. The precipitate was then dried and ignited over a Bunsen burner, first gently, then at full red heat until a constant weight was obtained, care being taken to avoid the reducing action of any unburned gas from the burner.

The following results were obtained :

No. of exp.	CdO taken. grm.	CdO found. grm.	Error. grm.
1.	0.1277	0.1275	—0.0002
2.	0.1277	0.1280	+0.0003
3.	0.1277	0.1272	—0.0005
4.	0.1399	0.1391	—0.0008
5.	0.1399	0.1399	±0.0000
6.	0.1703	0.1700	—0.0003
7.	0.1703	0.1700	—0.0003
8.	0.2129	0.2128	—0.0001
9.	0.2129	0.2128	—0.0001
10.	0.2554	0.2554	±0.0000

The method is simple in execution, and the above results prove its accuracy.

Some of the older manuals also give as a method for the estimation of cadmium that of igniting to the oxide the precipitated hydroxide obtained by adding a solution of sodium or potassium hydroxide to the solution containing the salt of cadmium. Follenius has published* some results obtained with the use of an asbestos filter, and it was decided to try this method in comparison with the carbonate method. As in the experiments with the carbonate, portions of the solution of cadmium sulphate were carefully measured off from a burette, diluted to about 300^{cm}³, and heated to boiling. A 10 per cent solution of potassium hydroxide was then added drop by drop and the whole boiled for about fifteen minutes. Upon cooling, the precipitate quickly settled in a semi-granular state,

* Z. anal. Ch., xiii, 284 (1874).

and was best filtered and washed by decantation. The results were lower than when the cadmium was precipitated as the carbonate, as is shown by the following table :

No. of exp.	CdO taken. grm.	CdO found. grm.	Error. grm.
1.	0.1277	0.1277	± 0.0000
2.	0.1277	0.1270	-0.0007
3.	0.1277	0.1260	-0.0017
4.	0.1277	0.1286	$+0.0009$
5.	0.1362	0.1350	-0.0012
6.	0.1399	0.1389	-0.0010
7.	0.1703	0.1697	-0.0006
8.	0.1703	0.1693	-0.0010
9.	0.1703	0.1699	-0.0004
10.	0.1788	0.1802	$+0.0014$
11.	0.2129	0.2139	$+0.0010$
12.	0.2129	0.2128	-0.0001

While the figures show that fair results may be obtained by the hydroxide method, it can be compared with the carbonate method neither for accuracy nor convenience: the precipitate does not attain the same granular form as that of the carbonate; it is hard to filter, difficult to wash, and can be removed completely from the beaker in which precipitation takes place only with the utmost difficulty.

ART. XLIX.—*The Mounted Skeleton of Triceratops prorsus in the U. S. National Museum*; by C. SCHUCHERT. (With Plate XV.)

NOTE.—At various times articles on Triceratops by the late Professor Marsh have been printed in this Journal, and as the U. S. National Museum is the first institution to possess a mounted skeleton of this, the largest-headed Dinosaur, it is deemed advisable to complete the records by reproducing here the illustration recently published in the Proceedings of that Museum.* Mr. G. W. Gilmore did the mounting, and from his article the following extracts are taken :

Among the vertebrate fossils included in that part of the Marsh collection, now preserved in the United States National Museum, are the remains of several individuals pertaining to the large Cretaceous dinosaur, Triceratops. All of this material, which comes from the Laramie division of the Cretaceous, was collected by or under the supervision of the late Mr. J. B. Hatcher in the northeastern part of Converse County, Wyoming, a locality made historic by the researches

* Article 1426, vol. xxix, 1905, pp. 433-435, 2 plates.

of this enthusiastic student. From this one region he collected the remains of more than forty individuals of the *Ceratopsia*, a record that has never been equaled.

* * * * *

From the tip of the beak to the end of the tail the skeleton as restored is 19 feet 8 inches in length. The skull, which is 6 feet long, equals nearly one-third of this length. At the highest point (the top of the sacrum) it is 8 feet 2 inches above the base. The mounted skeleton presents several features which would otherwise be lost to the observer if seen in the disarticulated condition. The short body cavity, the deep thorax, the massive limbs, and the turtle-like flexure of the anterior extremities are characters only appreciated in the mounted skeleton. The position of the fore limbs in the present mount appears rather remarkable for an animal of such robust proportions, but a study of the articulating surfaces of the several parts precludes an upright mammalian type of limb, as was represented by Marsh in the original restoration. Moreover, a straightened form of leg would so elevate the anterior portion of the body as to have made it a physical impossibility for the animal to reach the ground with its head. . . . In constructing these parts we have followed Marsh's drawing, assisted somewhat by fore-foot material kindly loaned by Dr. H. F. Osborn, of the American Museum of Natural History, New York City.

The nasal horn of the skull used in the present skeleton appears to be missing, and on account of the unsatisfactory evidence as to whether the horn is wholly or only partly gone, it was decided not to attempt a restoration at this time. This will account for the absence of one of the important features upon which the name of the animal is based, *Triceratops* meaning three-horn face, in allusion to the presence of the two large horns above the eyes and the third smaller horn on the nose.

It may be of interest to mention here that Prof. O. C. Marsh used this skeleton (No. 4842), supplemented by other remains now preserved in the collections of the Yale Museum, for the basis of his restoration of *Triceratops prorsus*, published as Plate LXXI in the *Dinosaurs of North America*. . . . A comparison of the above restoration by Marsh with the mounted skeleton [see Plate XV] shows several differences in points of structure, due chiefly to the better understanding of these extinct forms. The most striking dissimilarity is in the shortening of the trunk by a reduction of the number of presacral vertebræ. . . . Mr. Hatcher determined, from a well-preserved vertebral column in the Yale Museum, the number of presacrals as twenty-one, this being six less than ascribed to the animal by Marsh.

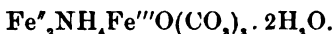
SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *A New Formation of Diamond.*—In a lecture delivered before the British Association at Kimberly, South Africa, Sept. 5, 1905, SIR WILLIAM CROOKES stated that he had found what were, in all probability, microscopic diamonds in residues obtained by Sir Andrew Noble in exploding cordite in closed steel cylinders. Crookes had calculated the theoretical melting point of carbon as 4400° absolute, and the melting pressure as 16.6 atmospheres; hence he concluded that the conditions of the cordite explosions, where a pressure of 8000 atmospheres and a temperature reaching in all probability 5400° absolute, would be favorable for the formation of diamonds. Upon examining the residues from such explosions, octahedral crystals were found which had high index of refraction, the proper cleavage, and the absence of birefringence of the diamond, and, although their other properties have not yet been determined, the chemical ordeal to which they were subjected in the treatment of the material leads to the belief that they must be diamonds.—*Chem. News*, xcii, 148.

H. L. W.

2. *A New Compound of Iron.*—OTTO HAUSER has prepared a curious ammonium-ferrous-ferric basic carbonate, evidently a triple salt, to which he gives the formula



It may be prepared, in the form of a crystalline precipitate, as follows: Ammonium-ferrous sulphate is dissolved in five parts of water, then a solution of commercial ammonium carbonate in about five parts of water is added until the precipitate which forms at first has redissolved. The quickly filtered liquid is then placed in a loosely closed bottle where only a small surface of the solution is exposed to the air. The liquid now becomes brown very rapidly from the top downward without any separation of ferric hydroxide, and in about half an hour a slightly greenish precipitate settles to the bottom, and after about two days the iron is completely removed from the solution in the form of the new compound. The substance has a light green color when fresh, but it rapidly darkens upon exposure to the air. It dissolves readily in acids with effervescence; it gives a black ferrous-ferric oxide with alkalies, and at the same time evolves ammonia.—*Berichte*, xxxviii, 2707.

H. L. W.

3. *Nitrosyl Fluoride.*—RUFF and STÄUBER, by the action of nitrosyl chloride upon silver fluoride have prepared this substance, NOF. It is a colorless gas which melts at about -134° and boils at -56° . In its chemical activity it resembles free fluorine

as well as nitryl fluoride, NO_2F , which has been prepared by Moisson, but from the latter it differs in its density, in reacting readily with iodine to form iodine pentafluoride, and in reacting with water to form nitrous acid instead of nitric acid.—*Zeitschr. Anorgan. Chem.*, xlvii, 190.

H. L. W.

4. *The Atomic Weight of Strontium*.—About ten years ago T. W. RICHARDS determined the atomic weight of strontium by means of a comparison of the bromide with silver. He now publishes the results of a comparison of the chloride with silver, made several years ago, but not published at the time on account of a discrepancy in the results due to an unknown cause. This discrepancy has been explained by the recent revision of the relation between silver and chlorine made by Richards and Wells, and it is found that the averages of the two series of determinations agree with remarkable closeness when the correction in the atomic weight of chlorine is made; thus :

From SrBr_2 , $\text{Sr} = 87.663$

From SrCl_2 , $\text{Sr} = 87.661$

These results are based on silver as 107.930, but Richards remarks that this number is probably not exact in comparison with oxygen as 16, and that the result will require modification when the true atomic weight of silver has been determined.—*Zeitschr. Anorgan. Chem.*, xlvii, 145.

H. L. W.

5. *Qualitative Analysis*; by E. H. S. BAILEY and H. P. CADY. 8vo, pp. 278. Philadelphia, 1905, P. Blakiston's Son & Co.—This book is interesting in being based upon the application of the theory of electrolytic dissociation and the law of mass action; but, however important these principles may be considered in connection with teaching the subject, it appears that the extent to which they are carried in this case often causes a loss of clearness and conciseness as far as qualitative analysis is concerned. It may be mentioned that the book is not as large as its pages would indicate, for nearly half of them are left blank for use in keeping notes.

H. L. W.

6. *Charging Effect of Röntgen Rays*.—The ionizing effect of these rays has been apparently fully proved, and there is a satisfactory agreement in the results of observers. This is not, however, true in regard to the question whether the rays give various bodies upon which they impinge electric charges. The subject has been investigated by KARL HAHN, whose results support the contention of Prof. J. J. Thomson, that the rays give a positive charge to bodies. His results are summed up as follows :

(1) All bodies upon which the rays directly impinge are charged positively.

(2) Very thin sheets of metals are charged more strongly than thick sheets, and the difference is greater the shorter the exposure to the rays.

AM. JOUR. SCI.—FOURTH SERIES, VOL. XX, No. 120.—DECEMBER, 1905.

(3) The influence of the character of the metal surface is negligible.

(4) The potential of the charged plate is dependent upon :

(a) The capacity with which the plate is connected ;—the quantity of electricity, that is, the product of capacity and potential is smaller for the greater potential, that is for smaller capacity. If we assume that this is due to the conductivity of the air, one can assume that the quantity of electricity is constant.

(b) The time of exposure to the rays. The potential increases with the time of exposure up to 20 sec. and then remains constant.

(c) On the nature of the rays. Hard rays exert a stronger influence than weak rays.

(d) On the nature of the metals ; the potential is greater the greater the atomic weight, and the more the metal is electronegative. The influence of atomic weight is more notable with the hard rays ; the position of the metals in the electromotive series has greater effect in the case of the weak rays.

(e) On the surrounding gas. The potential is greater in air than in CO_2 .

(5) Secondary rays tend to neutralize the charges. This phenomenon explains the discordant results obtained by various observers.—*Ann. der Physik*, No. 11, 1905, pp. 140–171. J. T.

7. *Emission of Negative Corpuscles by the Alkali Metals.*—Elster and Geitel discovered that even the light emitted by a glass rod heated to a dull red heat was sufficient to cause rubidium to emit corpuscles. Professor J. J. THOMSON shows that rubidium and the liquid alloy of sodium and potassium give out corpuscles in the dark. This result leads Professor Thomson to speculate upon probable differences of temperature between the interiors of bodies and their surfaces arising from the explosion of atoms.—*Phil. Mag.*, Nov. 1905, pp. 584–590. J. T.

8. *A New Method of showing the Presence of Neon, Krypton, and Xenon.*—S. VALENTINER and R. SCHMIDT depart somewhat from the method of Dewar, by which, using the singular occlusion power of charcoal at low temperatures, Dewar showed the presence of neon, hydrogen and helium. Valentiner and Schmidt exhaust the spectrum tube and connected apparatus ; then admit a large quantity of argon, submit this argon to the occlusion action of charcoal at the temperature of liquid air. By this process neon is left in the spectrum tube ; and the quantity can be suitably increased by varying the pressure and amount of exhaustion. Suitable modifications of this method of employing argon as a basis and the occluding power of charcoal at different low temperatures enabled the authors to show the presence of krypton and xenon.—*Ann. der Physik*, No. 11, 1905, pp. 187–197. J. T.

9. *The Mechanical Properties of Catgut Musical Strings ; a Correction* by J. R. BENTON (communicated).—I have to correct

an error in my article on the Mechanical Properties of Catgut Musical Strings, which appeared in the last issue of this Journal. On page 384, under the heading "Hygroscopic Properties," some observations are discussed which appear to show that the string in question increased in length with increasing humidity; although, as mentioned there, its behavior was much complicated by after-effects. It is well known that the catgut strings of musical instruments are affected by changes of humidity: but they tend to *contract* with increasing humidity, and not to *stretch*, as stated in the article. The string on which I made observations showed just the opposite behavior; but it was under different conditions from the strings in musical instruments. In the first place, it was under far less tension; in the second place, it was free from any torsion; consequently any lateral swelling of its fibers which might occur would have no tendency to shorten it, while such swelling would tend to shorten a twisted string.

II. GEOLOGY AND MINERALOGY.

1. *Iowa Geological Survey, Volume XV. Annual Report, 1904, with accompanying papers.* FRANK A. WILDER, State Geologist; T. E. SAVAGE, Assistant Geologist. Pp. viii, 560, 7 plates, 51 figures and 10 geological maps. Des Moines, 1905.—The Geological Survey of Iowa, under the charge of Professor Samuel Calvin, has enjoyed an excellent reputation for the thorough and systematic work which it has accomplished since its inauguration. Professor Calvin has now found it necessary to resign from the position of chief responsibility, and the place has been filled by Professor Frank A. Wilder, under whose auspices the present volume has been published. This volume gives promise that the future work done for the State will be carried forward on the same lines and with the same excellent results that have characterized its predecessors.

The volume contains, in addition to the administrative report, a chapter on the Mineral Production in 1904, by S. W. Beyer; another on Cement and Cement Material, by E. C. Eckel and H. F. Bain; and then a series of chapters discussing in detail the geology of a number of counties accompanied by geological maps. These special reports include the following: On the Geology of Benton County, by T. E. Savage; of Emmet, Palo Alto and Pocahontas Counties, by Thomas H. Macbride; of Jasper County, by Ira A. Williams; of Clinton County, by Jon Andreas Udden; of Fayette County, by T. E. Savage. It is stated that the field work for 1905 is being carried on preëminently along economic lines, the earlier stratigraphic work having laid the necessary foundation.

In the report of Mr. Beyer alluded to above, it is shown that the value of the mineral productions of the State in 1904 was

\$15,000,000, of which the chief items are coal, making two-thirds of the whole, and clay more than a fifth; others are building stone, gypsum, lead and sand-lime brick.

2. *Summary Report of the Geological Survey Department of Canada, for the Calendar Year 1904.* ROBERT BELL, Acting Deputy Head and Director. Pp. xxxviii, 392, with seven geological maps. Ottawa, 1905. — This volume gives a concise account of the work accomplished by the Canadian Survey during 1904. The total number of parties engaged was twenty-eight, and their labors extended over the entire area of the country, extending not only from the Atlantic to the Pacific but also into the Arctic. In general, the work carried on, as with other surveys at the present time, was largely on the economic side. As an illustration of what may be accomplished in this way by careful geological work, the Director mentions the recent discovery of a seam of coal, 10 feet thick, at a depth of 2,340 feet, near Pettigrew, in Cumberland County, Nova Scotia. The bore-hole was sunk through an unproductive covering at the suggestion of Mr. Hugh Fletcher of the Survey, as the result of his knowledge of the minute structural geology of that district. This successful result opens the prospect of finding numerous coal seams through an area of fifty miles in length and thirty in breadth. This discovery is given as an illustration of the very important economic results that follow accurate topographical and geological work.

Of the special reports given in the volume, two are devoted to the Kluane and Duncan Creek mining districts, in Yukon Territory, others to the different coal-basins of British Columbia and so on. An interesting account is also given by Commander A. P. Low of the expedition to Hudson Bay and northward in 1903–4 by the S. S. Neptune. Among other points may be mentioned a detailed statement of the phenomena accompanying the fall of the meteorite at Shelburne, Ontario, on August 13, 1904.

3. *Glaciation of Southwestern New Zealand.* — E. C. ANDREWS, of the Department of Mines, Sydney, New South Wales, has written on "Some interesting facts concerning the glaciation of Southwestern New Zealand" (Trans. Austral. Assoc. Adv. Science, 1904, 189–205, 8 plates), in which he sets forth with much clearness the evidence of intense glacial erosion in the district of the fiords about Milford sound. Hanging lateral valleys, partially or totally truncated spurs, and the resulting rectilinear cliffs or over-steepened valley sides, with lakes and over-deepened fiords along the valley courses all occur in abundance. These peculiar features are compared with those developed by normal erosion in the highlands of northeastern Australia ("New England"), and the conclusion is reached that as normal erosion cannot possibly account for both, glacial erosion must be responsible for the peculiar features that occur where glaciers are independently shown to have existed. In a supplementary note, Andrews

well says: "The author feels confident that the glacial explanation is most convincing to students of geography, who . . . have not either lived in or even seen any region of former or present intense glaciation. Only to such workers does the whole series of novel perceptions presented during a first glimpse at a former strongly glaciated region come with the startling force of a revelation."

W. M. D.

4. *Mastodon-Reste aus dem interandinen Hochland von Bolivia*; von J. F. POMPECKJ. *Palaeontographica*, Bd. 52, 1905, pp. 17-56, 2 pls.—Dr. Pompeckj, during his travels in Bolivia in 1902, collected near Ulloma and Calacoto a number of mastodon jaws and teeth here described and discussed in great detail. These were found at an elevation of 3800 meters above sea level, and belong to *Mastodon boliviannus* and *M. humboldti*.

The belief is held by some that these mastodons lived at a time when the mountains had a far lower altitude than now, but Pompeckj holds quite the contrary opinion. He states:

"During Diluvial time, or at least during that portion of it when the fauna containing *Mastodon boliviannus* existed, the high Bolivian plains at an elevation of about 3800-4000 meters probably had the character of a steppe, similar to that of to-day, but with a greater rainfall and therefore with a richer growth of grass and bushes than at present.

"Neither the geological structure of the Bolivian highland nor its Diluvial fauna compels the conclusion of decided Diluvial or Postdiluvial elevation of the Andes."

C. S.

5. *Description of New Rodents and Discussion of the Origin of Daemonelix*; by O. A. PETERSON. *Mem. Carnegie Museum*, ii, 1905, pp. 139-191, text figures and pls. 17-21.—The part of this paper of greatest interest in general paleontology relates to the interpretation of the so-called "Devil's corkscrews," so well and fully described by Professor Barbour. The general explanation has been that these gigantic screw casts are the fossilized and infiltrated roots of water plants. However, the suggestion has also been made that they represent the burrows of some fossorial rodent.

Last year Mr. Peterson made a careful search for vertebrate fossils in the *Daemonelix* beds as exposed in the adjoining counties of Sioux in Nebraska and Converse in Wyoming. He states that one is always sure to find rodent remains in a locality where *Daemonelix* is found in great numbers, and he was rewarded in his exploration by securing a number of good skeletons of the beaver-like *Steneofiber* within the spiral of *Daemonelix* or its so-called rhizome. This led him next to study the tunnels of the living prairie-dog so common throughout the semi-arid region of the West. He did this by making a mixture of plaster, water, and sand, and pouring this into and filling the tunnel. Later this filling was dug out, and two of these casts are illustrated in the paper here reviewed; they certainly suggest

Daemonelix. The rhizomes of the gigantic corkscrew were found to be either simple or several times branched ; some of them ended in an enlargement, but none of them showed small *Daemonelix* spirals emerging from them, as has been stated by other authors. The skeletons within *Daemonelix* are usually scattered "and quite often only the head is found crowded close to the wall, or inside of the rim of the compact mass of roots." The best skeleton was found near the end of one of the rhizomes. Some of the latter attained a length of fifteen feet.

In regard to the plant material found within the spirals, Mr. O. E. Jennings states : "The vegetable tissues are apparently simply the remains of a mesh of roots such as is sometimes found clogging a tile drain or sewer. . . . Enough was evident, however, to plainly indicate that nearly all the roots were those of angiosperms, the cells discerned being quite typical."

The evidence thus far presented is decidedly more in favor of *Daemonelix* being the cast of fossorial rodent burrows than the roots of some gigantic aquatic plant. c. s.

6. *Economic Geology of the Bingham Mining District, Utah*; by JOHN MASON BOUTWELL; with A Section on Areal Geology, by ARTHUR KEITH and An Introduction on General Geology, by SAMUEL FRANKLIN EMMONS. U. S. G. S. Professional Paper, No. 38, 396 pp., 49 pls., 10 figs. in text. — This paper, which almost approaches a monograph in size and scope, is a valuable contribution to the literature of economic geology as well as being a detailed description of an important and interesting mining district. Bingham has been a producing camp since about 1870. In the early days of the district the lead-silver deposits were worked, the carbonate ores being first mined and then later the sulphides. Some gold mining has also been carried on, both placer and vein deposits. In 1896 large bodies of low-grade copper ore were first seriously exploited and since then Bingham has steadily risen in importance as a copper producer. The production of copper from the district for the year 1902 was nearly 15,000,000 lbs.

The Bingham district is situated on the east side of the Oquirrh Mountains about fifteen miles south of Great Salt Lake. The rocks of the section are made up chiefly of quartzites, sandstones and limestones of Upper Carboniferous age, with intrusive bodies of monzonite and monzonite porphyry and extrusive flows of andesite. There is one broad open flexure of the rocks in the district, a synclinal fold which pitches toward the northwest. Besides this many smaller folds are found. The rocks are also extensively faulted.

The ores occur in vein, bedded and disseminated deposits. The vein deposits are chiefly those of argentiferous lead ore which fills fissures that traverse all of the rock types. The bedded deposits are of copper ore and are found in the limestones, while the disseminated copper ore is restricted to the monzonitic intrusives.

The most important ore bodies are those of the copper-bearing sulphide deposits which occur in massive marbleized limestones along particular beds in the vicinity of the intrusives.

Mr. Boutwell sums up the geological history of the district as follows: "Between Carboniferous and late Tertiary time monzonitic intrusives invaded sediments in the Bingham area, metamorphosed them and introduced metallic elements which replaced marbleized limestone with pyritous copper sulphides. After the superficial portions of the intrusives had cooled to at least partial rigidity they and the inclosing sediments were rent by northeast-southwest fissures.

"Heated aqueous solutions from the deeper unconsolidated portions of the magma then ascended these channels, altered their walls, and introduced additional metallic elements. At this time more pyritous copper sulphide may have been added to that formed earlier in the limestone in connection with contact metamorphism. Monzonite, including its original metallic constituents, was altered; copper, gold and sulphur were probably added, and auriferous copper sulphides were formed. The silver-lead ore was deposited in the fissures, mainly by filling, partly by replacement.

"Since this period of mineralization these original sulphide ores have been altered by surface waters, in their upper portions, into carbonates and oxides, and relatively enriched in their underlying portions."

W. E. F.

7. *Economic Geology, a Semi-Quarterly Journal devoted to Geology as applied to Mining and Allied Industries.* Volume I, Number 1. (Published by the Economic Geology Publishing Company, Lancaster, Pa.)—The appearance of the first number of this new journal is an event of unusual interest and importance. Economic geology has only within the last quarter century established its place as a distinct and important department of geological science. In Germany the *Zeitschrift für praktische Geologie* was the result of this movement among German geologists and it has done much to place this branch of geology on a firm basis both at home and abroad. It is only recently, however, that in the English-speaking world economic geology has begun to occupy its rightful position, and this new journal has been established on account of this fact and with the hope that by its efforts a still larger recognition may be given the subject. Until now the American geologist who had interested himself in the problems of ore deposits had no field for the publication of the results of his investigations outside of the channels of the United States Geological Survey, except in various technical or semi-technical journals devoted to mining. It is, therefore, with a distinct sense of congratulation that we find provided here a proper place for the printing of such papers.

The editor outlines the scope and office of the journal in his first editorial as follows: "The chief purpose of 'Economic Geol-

ogy' will be to furnish its readers with articles of a scientific character. These will deal with the application of the broad principles of geology to mineral deposits of economic value, with the scientific description of such deposits and particularly with the chemical, physical and structural problems bearing upon their genesis. With the engineering and commercial aspects of mining this journal will not be directly concerned, as these subjects find ample representation in the technical mining journals."

The editor of "Economic Geology" is Prof. J. D. Irving of Lehigh University, and the associate editors; Mr. W. Lindgren of Washington, Prof. J. F. Kemp of Columbia University, Mr. F. L. Ransome of Washington, Prof. H. Ries of Cornell University, Mr. M. R. Campbell of Washington and Prof. C. K. Leith of the University of Wisconsin.

The magazine in its mechanical make-up has evidently been modeled after the Journal of Geology. The paper, type, and general appearance are all excellent. The first number embraces 100 pages, of which about three-fourths are given to articles, whose titles are as follows: The Present Standing of Applied Geology, by F. L. Ransome; Secondary Enrichment in Ore-Deposits of Copper, by J. F. Kemp; Hypothesis to Account for the Transformation of Vegetable Matter into the Different Varieties of Coal, by M. R. Campbell; Ore-Deposition and Deep Mining, by W. Lindgren; Genesis of the Lake Superior Iron Ores, by C. K. Leith; The Chemistry of Ore-Deposition—Precipitation of Copper by Natural Silicates, by E. C. Sullivan. There are also sections devoted to the informal discussion of topics relating to economic geology, to reviews and to scientific notes and news.

W. E. F.

8. *Minerals in Rock Sections; the practical methods of identifying Minerals in Rock Sections by means of the Microscope*; by LEA McL. LUQUER. Revised Edition. 147 pp. New York, 1905 (D. Van Nostrand Co.).—The additions and changes introduced in the revised edition of this useful volume (see vol. vii, 319) are numerous and such as to materially increase its value for the practical worker with the microscope.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences*.—The autumn meeting of the National Academy was held at New Haven, Conn., on November 14 and 15. The following list contains the titles of papers read:

JOHN TROWBRIDGE: Slow movements of electrical discharges.

E. B. WILSON: Sex-determinations and the chromosomes.

L. B. MENDEL: Studies on the chemical physiology of development and growth.

W. M. DAVIS: The Dwyka glacial conglomerate of South Africa.

B. B. BOLTWOOD: The disintegration products of thorium as indicated by the proportions of lead and helium in minerals.

A. HALL : Relation of the true anomalies in a parabola and a very eccentric ellipse having the same perihelion distance.

S. L. PENFIELD : On a new mineral from Borax Lake, California.

F. E. BEACH : On errors of excentricity and collimation in the human eye.

C. S. PEIRCE : The relation of betweenness and Royce's O-collections.

L. P. WHEELER : Some problems in metallic reflection.

FRANZ BOAS : On Pearson's formulas of skew distribution of variates.

A. AGASSIZ : On the variation in the spines of sea urchins.

W. H. BREWER : Further observations on sedimentation.

H. A. BUMSTEAD : The effect of Röntgen rays on certain metals.

Recent publications of the Academy are as follows :

Memoirs, Vol. IX.—Monograph of the Bombycine Moths of North America, including their Transformations and Origin of the Larval Markings and Armature. Part II, Family Ceratocampidæ, Subfamily Ceratocampinæ ; by ALPHEUS SPRING PACKARD. 149 pp., 61 plates, in part colored.

Vol. X, No. 1.—The Absolute Value of the Acceleration of Gravity determined by the Ring-Pendulum Method ; by CHARLES E. MENDENHALL. Pp. 1-23, 3 plates.

No. 2.—Claytonia Gronov, a Morphological and Anatomical Study ; by THEODORE HOLM. Pp. 25-37, 2 plates.

No. 3.—A Research upon the Action of Alcohol upon the Circulation ; by HORATIO C. WOOD and DANIEL M. HOYT. Pp. 39-88, 3 plates.

2. *The Geological Society of America*.—The eighteenth winter meeting of the Geological Society will be held at Ottawa, Dec. 27-29, in the House of Commons Building ; this is by invitation of the Logan Club of the Geological Survey of Canada. President R. Pumpelly will preside. The Cordilleran Section of the Society will meet at Berkeley, Cal., Dec. 29, 30.

3. *A Laboratory Guide in Bacteriology* ; by PAUL G. HEINEMANN. 143 pp. 1905 (The University of Chicago Press).—This little manual of 143 pages contains clear and concise directions for a thorough course of laboratory work in the subject, including the preparation of culture and staining media and the collection, isolation, and method of studying the different groups of bacteria. The course, as outlined, is that pursued by the medical students of the University of Chicago. There are descriptions and illustrations of practically every piece of apparatus used in the laboratory. Between each two pages is a blank sheet for notes and additions to the text.

W. R. C.

4. *British Tunicata* ; by ALDER and HANCOCK, edited by the Secretary of the Ray Society. Vol. I. Ray Society, 1905. Pp. 146, with 20 plates.—This long delayed monograph, that was begun in 1855, has now made its appearance, more than thirty years after the death of both the authors. The entire work will be completed in three volumes and will contain descriptions and colored illustrations of all the British tunicates known up to the year 1873. The present volume contains a general account of the anatomy, physiology and relationships of the class Tunicata, together with extended specific descriptions of the thirty indige-

nous species of the genus *Ascidia*. Nearly all these forms are illustrated by beautiful colored drawings by the authors. There are also many anatomical figures. W. B. C.

5. *Catalogus Mammalium tam viventium quam fossilium* a Doctore E.-L. TROUESSART. Quinquennale Supplementum (1899-1904) Fasciculus IV. Pp. vii, 753-929, Berlin, 1905 (R. Friedländer & Sohn).—This part completes the Supplement begun in 1904 (this Journal, xviii, 95) and gives the volume contents and index. It includes the Cetacea, Edentata, Marsupialia, Allothéria, Monotremata.

6. *Carnegie Institution of Washington*.—Recent publications, not before announced, are as follows:

No. 9.—The Collected Mathematical Works of GEORGE WILLIAM HILL. Volume one. Pp. xviii, 363. With an introduction by M. H. Poincaré and a portrait (frontispiece).

No. 35.—Investigations of Infra-red Spectra. Part I, Infra-red Absorption Spectra; Part II, Infra-red Emission Spectra; by WILLIAM W. COBLENTZ. 331 pp., 152 figures, 3 folded plates.

No. 36.—Studies in Spermatogenesis, with especial reference to the "Accessory Chromosome"; by N. M. STEVENS. 30 pp., 7 plates.

No. 37.—Sexual Reproduction and the Organization of the Nucleus in certain Mildews; by R. A. HARPER. 104 pp., 7 plates.

No. 41.—Traditions of the Caddo, collected under the auspices of the Carnegie Institution of Washington; by GEORGE A. DORSEY. 136 pp.

7. *A Handbook of the Trees of California*; by ALICE EASTWOOD, Curator of the Department of Botany. Occasional Papers of the California Academy of Sciences, IX. 86 pp., 57 plates. San Francisco, 1905.—The scope of this work will be seen from the following statement quoted from the preface: "The aim has been to prepare a work which, while giving all the information necessary for the identification of the different trees of our valleys and mountains, will be so brief and concise that the entire matter can be put into a book that can be carried into the field." The description of species are quite brief, but are well supplemented by a series of 57 excellent plates.

OBITUARY.

Professor DEWITT BRISTOL BRACE, head of the Department of Physics in the University of Nebraska and author of numerous physical papers, died at his home in Lincoln, Nebraska, on October 2, in his forty-seventh year.

Professor RALPH COPELAND, Astronomer Royal of Scotland and Professor of Astronomy in the University of Edinburgh, died on October 27, at the age of sixty-eight years.

Dr. W. VON BEZOLD, Professor of Physics and Meteorology at the University of Berlin and Director of the German Meteorological Institute, died early in October, in his sixty-ninth year.

INDEX TO VOLUME XX.*

A

- Academy**, National, New Haven meeting, 468; publications, 469.
Aldrich, J. M., catalogue of No. American diptera, 77.
Allen E. T., thermal properties of feldspars, 72.
Alpen, die, im Eiszeitalter, Penck and Brückner, 407.
American Museum Journal, 77.
Arizona, petrography of Tucson Mts., Guild, 313.
Ashley, R. H. estimation of sulphites by iodine, 13.

B

- Bacteriology**, Heinemann, 469.
Bailey, E. H. S., Qualitative Analysis, 461.
Barus, C., groups of efficient nuclei in dust-free air, 297; ions and nuclei in dust-free air, 448.
Baskerville, C., phosphorescence of zinc sulphide, 98; action of radium emanations on minerals, 95.
Becker, rock cleavage, 407.
Belknap Mts., N. H., geology, Pirsonton and Washington, 344.
Benton, J. R., properties of catgut musical strings, 383, 462.
Bières, Fabrication, Moreau and Lévy, 168.
Blondlot's Emission pesante, 400.
Bolivia, mastodon remains, Pompeckj, 465.
Boltwood, B. B., radium and uranium in radio-active minerals, 55; radio-active waters, Hot Springs, Ark., 128; disintegration products of radio-active elements, 253; production of radium from uranium, 239.

BOTANY.

- Croomia pauciflora**, Holm, 50.
Cyperaceæ, studies in the, Holm, No. XXIV, 301.
Trees of California, Eastwood, 470,
British Museum, Catalogue of Birds' Eggs, Oates, 412.

- Bronson, H. L.**, effect of temperature on rate of decay of radium deposit, 60.
Brown, T. C., Lower Tertiary fauna of Chappaquiddick Is., 229.
Brückner, E., die Alpen im Eiszeitalter, 407.
Bush, K. J. tubicolous annelids from Pacific, 75.

C

- Cady, H. P.**, Qualitative Analysis, 461.
Campbell, H. D., Cambro-Ordovician limestones of Virginia, 445.
Canada geol. survey, 1904, 464.
Canadian Rockies, glacial studies, Scherzer, 80.
Cape Colony, Geology, Rogers, 163.
Carnegie Institution, publications, 80, 411, 470.
Carolinas, tin deposits of, Sterritt and Pratt, 75.
Cathode, rotating, for estimation of cadmium, Flora, 268, 392, 455.
Chemical Arithmetic, Wells, 399.

CHEMISTRY.

- Actinium**, gases from, Debiérne, 319.
Aluminium, iodometric determination, Moody, 181.
Bromides, typical hydrous, Kreider, 97.
Cadmium, estimation of, as sulphate, Flora, 268; as chloride, Flora, 392; as oxide, Flora, 457; by rotating cathode, Flora, 455.
Ferric sulphate solutions, hydrolysis of, Recoura, 320.
Gold, separation from platinum metals, Jannasch and von Mayer, 320.
Helium from radium emanation, Himstedt and Meyer, 399.
Hydrogen, liquid, and air calorimeters, Dewar, 152; nascent, diffusion through iron, Winkelman, 400.
Iron, new compound, Hauser, 460.

* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

CHEMISTRY *continued.*

- Neon and helium in the air, Ramsay, 65.
 — krypton and xenon, new method of detecting, Valentiner and Schmidt, 462.
 Nickel, new reagent for, Tschugaeff, 397.
 Nitrosyl fluoride, Ruff and Stäuber, 460.
 Ozone, formation by ultra-violet light, Fischer and Braemer, 397.
 Precipitates, handling of, Gooch, 11.
 Radium. See **Radium**.
 Solution, new heavy, Duboin, 319.
 Strontium, atomic weight, Richards, 461.
 Sugar, determination with Fehling's solution, 320.
 Sulphites, estimation by iodine, Ashley, 13.
 Thorium, radio-activity of, Sackur, 65.
 Zinc sulphide, phosphorescence, Baskerville and Lockhart, 95.

Chemistry, Engineering, Stillman, 398.

- Inorganic, Gooch and Walker, 66.
 Physiological, Long, 399.
 Qualitative Analysis, Bailey and Cady, 461.

Cincinnati. See **Observatory**.

- Cleland, H. F., formation of natural bridges, 119.

Conn, H. W., protozoa of Connecticut, 76.**Connecticut**, clays of, Loughlin, 408.**Crinoids**, Helderbergian, of New York, Talbot, 17.**Cumings E. R.**, development of Fenestella, 169.**Cushing, H. P.**, geology of Little Falls, N. Y., 156.**D****Daly R. A.**, secondary origin of granites, 185.**Darton, N. H.**, age of Monument Creek formation, 178; geology and water resources of Central Great Plains, 70.**Davison C.**, Recent Earthquakes, 163.**Day, A. L.**, thermal properties of feldspars, 72.**Dewar, J.**, liquid hydrogen and air calorimeters, 152; thermo-electric junction for determining temperatures, 153.**E****Earthquakes**, Recent, Davison, 163.**Eastwood, A.**, Trees of California, 470.**Electricity**, side discharge of, Trowbridge, 57.**Electrolytic** dissociation theory, Talbot and Blanchard, 398.**F****Fairchild, H. L.**, ice erosion theory, a fallacy, 164.**Feldspars**, see **MINERALS**.**FitzGerald-Lorentz** effect, Morley and Miller, 67.**Flora, C. P.**, estimation of cadmium as sulphate, 268; do. as chloride, 392; do. as oxide, 457; do. by rotating cathode, 455.**Forestry**, report for Minnesota, 1904, 167.**Fossils**, see **GEOLOGY**.**G****Gardiner, J. G.**, Fauna and Geography of the Maldives and Laccadives, Vol. ii, pt. iv, 77.**Gas** mixtures, Spectroscopic Analysis, Lilienfeld, 67.**Geikie, J.**, Structural and Field Geology, 408.**GEOLOGICAL REPORTS** and **SURVEYS**

Canada, 1904, 464.

Cape of Good Hope, 1904, 406.

Indiana, 29th annual report, 322.

Iowa, Vol. xv, 1904, 463.

Louisiana, bulletins, 323.

New Jersey, 1904, 323.

United States, 69, 402.

Geological Society of America, Ottawa meeting, 469.**GEOLOGY**.**Baptanodon**, osteology, Gilmore, 403.**Bingham** mining district, Utah, geology, Boutwell, Keith and Emmons, 466.**Cambrian** faunas of India, Walcott, 404, 405.

GEOLOGY *continued.*

- Cambrian, Lower, fauna of, Portugal, Delgado, 159.
 Ceratopsia, two new, Wyoming, Hatcher, 413.
 Chazy limestone, fauna of, Raymond, 353.
 Clays of Connecticut, Loughlin, 408.
 Daemonelex, origin of, Peterson, 465.
 Diceratops, restoration, Lull, 420.
 Faults, overthrust, in central New York, Schneider, 308.
 Fenestella, development, Cumings, 169.
 Fossil Invertebrates, Catalogue, U. S. Nat. Museum, Schuchert, 405.
 Geologic map of Tully Quadrangle, Clarke and Luther, 158.
 Geology of Bingham mining district, Utah, Boutwell, 466; of Central Great Plains, Darton, 70; of Little Falls, N. Y., Cushing, 156; of Littleton, New Hampshire, Hitchcock, 161; of Watkins and Elmira quadrangles, Clarke and Luther, 157.
 Glacial conglomerate of South Africa, Mellor, 107.
 —studies, Canadian Rockies, Scherzer, 80.
 Glaciation of the Green Mts., Hitchcock, 166; of New Zealand, Andrews, 464.
 Glacier, Delavan lobe of Lake Michigan, Alden, 409.
 Graptolites of New York, Ruedemann, 406.
 Helderbergian crinoids of New York, Talbot, 17.
 Ice erosion theory, fallacy of, Fairchild, 164.
 Limestones, Cambro-Ordovician of Virginia, Campbell, 445.
 Martinez group, paleontology, Weaver, 159.
 Mastodon remains from Bolivia, 465.
 Mesozoic plants from Korea, Yabe, 406.
 Monument Creek formation, age of, Darton, 178.
 Natural bridges, formation, Cleland, 119.
 Paraphorhynchus, new brachiopod, Weller, 160.
 Peat bogs of Switzerland, Früh and Schröter, 162.

GEOLOGY *continued.*

- Rock cleavage, Leith, 406, Becker, 407.
 Sympterura minveri, Devonian ophiurid, Bather, 160.
 Tertiary, Lower, fauna of Chappaquiddick Island, Brown, 229.
 Thalattosauria, California, Merriam, 161.
 Toxochelys, new Niobrara, Wieland, 325.
 Triassic system in New Mexico, Keyes, 423.
 Triceratops prorsus, mounted skeleton, Schuchert, 458.
 Turtles, marine, new, Wieland, 325; Upper Cretaceous, Wieland, 430.
 Unionidæ, origin of No. American, White, 160.
 Valleys, hanging, Russell, 165.
Geology, Economic, Journal of, 467.
 —of Cape Colony, Rogers, 163.
 —Structural and Field, Geikie, 408.
 Gilmore, C. W., osteology of Baptanodon, 403.
 Glaciation, Glaciers, see **GEOL-OGY**.
 Gooch, F. A., handling of precipitates for solution and reprecipitation, 11. Inorganic Chemistry, 66.
 Graton, L. C., purpurite, new mineral, 146.
 Green Mts., glaciation, Hitchcock, 166.
 Guild, F. W., petrography of the Tucson Mts., Arizona, 313.

H

- Harrington, B. J., apparatus for vapor densities, 225.
 Harvard College, see **Observatory**.
 Hatcher, J. B., two new Ceratopsia, Wyoming, 413.
 Heinemann, P. G., Laboratory Guide in Bacteriology, 469.
 Hidden, W. E., cassiterite, a new cleavage, 410.
 Hitchcock, C. H., glaciation of the Green Mts., 166.
 Hobbs, W. H., origin of channels around Manhattan Island, 71.
 Hofmeister, F., Beiträge zur chem. Physiologie, 168.
 Holm T., Croomia pauciflora, 50; studies in the Cyperaceæ, XXIV, Carices from N. W. America, 301.

Hough, R. H., mechanical equivalent of heat vaporization of water, 81.

Howorth, H. H., Ice or Water, 166.

I

Ice or Water, Howorth, 166.

Iddings, J. P., optical study of the feldspars, 72.

India, Cambrian faunas of, Walcott, 404, 405.

Indiana, geol. survey, 322.

Ions and nuclei in dust-free air, Barus, 448.

Iowa, geol. survey, 1904, 468.

J

Jamieson, G. S., tychite, 217.

Japan, magnetic survey, Tanakadate, 167.

K

Kayser, H., Handbuch der Spectroscopie, 69.

Keyes, C. R., Triassic system in New Mexico, 423.

Kilimandjaro to Meru, Africa, Uhlig, 78.

Korea, Mesozoic plants from, Yabe, 406.

Kreider, D. A., iodine titration voltmeter, 1.

Kreider, J. L., typical hydrous bromides, 97.

L

Laboratoire de l'Usine, Houillevegue, 168.

Lakes, A., Geology of Western Ore Deposits, 409.

Landolt-Börnstein Physikalisch-Chemische Tabellen, 401.

Leith, J. B., rock cleavage, 406.

Littleton, N. H., geology, Hitchcock, 161.

Lockhart, L. B., action of radium emanations on minerals, 95; phosphorescence of zinc sulphide, 98.

Long, J. H., Physiological Chemistry, 399.

Loughlin, G. F., Clays of Connecticut, 408.

Louisiana geol. survey, bulletins, 323.

Lull, R. S., restoration of Dicera-tops, 420.

Luquer, L. McL., Minerals in Rock Sections, 468.

M

Magnetic survey of Japan, Tanakadate, 167.

Maldives and Laccadives, Fauna and Geography, Gardiner, 77.

Manhattan Island, origin of channels around, Hobbs, 71.

Manila, ethnological survey, publications, 167.

Mastodon remains from Bolivia, Pompeckj, 465.

Mellor, E. T., glacial conglomerate of South Africa, 107.

Merriam, J. C., Thallatosauria from California, 161.

Metals, emission of negative corpuscles by alkali, Elster and Geitel, 461.

MINERALS.

Beckelite, 323. Bowmanite, 324.

Cassiterite, new cleavage, 410.

Diamond, formation, Crookes, 460.

Enargite, 280.

Feldspars, thermal properties, Day and Allen, 72; optical study, Iddings, 72.

Hematite, N. J., 288. Hutchinsonite, 324.

Lengenbachite, 324. Luzonite, 277. Marrite, 324.

Northupite, 217.

Platinum in black sands, Day, 410. Purpurite, 146.

Quartz, San Diego Co., Cal., 125. Riebeckite, genesis, 133.

Smithite, 324. Sylvanite, 282.

Tin deposits of the Carolinas, Pratt and Sterrett, 75. Trechmannite, 324. Tychite, 217.

Wolframite, Boulder, Colo., 281.

Minerals, action of radium emanations on, Baskerville and Lockhart, 95.

—in Rock Sections, Luquer, 468.

—optical character of birefracting, Wright, 285.

—radio-active, Rutherford and Boltwood 55; Strutt, 68.

Montana, Agricultural College, Science Studies, 78.

—petrography of Central, Pirsson, 35.

Moody, S. E., iodometric determination of aluminium, 181.

Murgoci, G. M., riebeckite and riebeckite rocks, 133.

Musical strings, properties of, Benton, 383, 462.

N

- Negritos of Zambale**, Reed, 167.
New Hampshire, geology of, Pirsson and Washington, 344.
New Jersey geol. survey, 1904, 323.
New Mexico, Triassic system, Keyes, 423.
New York, graptolites of, Ruedemann, 406.
 — Helderbergian crinoids, Talbot, 17.
 — overthrust faults in central, P. F. Schneider, 308.
New Zealand, glaciation, Andrews, 464.
Nobel prizes in 1902, 167.
Nuclei, efficient, in dust-free air, Barus, 297.

O

OBITUARY.

- Von Bezold, W., 470; Brace, D., 470; Buckton, G. B., 412.
 Copeland, R., 470.
 Errara, L., 412.
 Reclus, E., 412.
 Von Richthofen, F., 412.
Observatory, Cincinnati, 411; Harvard College, 411; Mt. Wilson, Cal., 80; West Hendon House, 80; Yerkes, 411.
Optical character of birefracting minerals, Wright, 285.
Ore deposits, Geology of western, Lakes, 409.

P

- Pacific**, tubicolous annelids from, Bush, 75.
Palæontologia Universalis, 406.
Penck A., die Alpen im Eiszeitalter, 407.
Penfield, S. L., tychite, 217.
Peterson, origin of Daemonelix, 465.
Physikalisch-chemische Tabellen, Landolt-Börnstein, 401.
Physiologie, Beiträge zur chem. Hofmeister, 168.
Pirsson, L. V., petrographic province of Central Montana, 35; geology of New Hampshire, 344.
Portugal, Lower Cambrian fauna, Delgado, 159.
Pumpelly, R., Explorations in Turkestan, 245.

Q

- Quartz apparatus for laboratory purposes**, Mylius and Meusser, 66.
 — permeability to gases, Berthelot, 66.

R

- Radio-active elements**, disintegration products, Boltwood, 253.
 — minerals, Rutherford and Boltwood, 55; Strutt, 68.
 — waters, Hot Springs, Ark., Boltwood, 128.
Radio-activity, absence of excited, due to temporary exposure to γ -rays, 68; of thorium, Sackur, 65.
Radium, action of emanations on minerals, Baskerville and Lockhart, 95.
 — effect of temperature on rate of decay of deposit from, Bronson, 60.
 — emanations, helium from, Himstedt and Meyer, 399.
 — production from uranium, Boltwood, 239.
 — slow transformation products, Rutherford, 321.
 — and uranium in radio-active minerals, Rutherford and Boltwood, 55.
Ramsay, neon and helium in air, 65.
Raymond, P. E., fauna of Chazy limestone, 353.

ROCKS.

- Andesites**, Arizona, Guild, 314.
Basalt, Arizona, Guild, 316.
Belknap Mts., N. H., Pirsson and Washington, 344.
Granites, secondary origin of, Daly, 185.
Petrographic province of Central Montana, Pirsson, 35.
Quartz-basalt, Arizona, Guild, 318.
Rhyolite, Arizona, Guild, 313.
Riebeckite rocks, genesis, Murgoci, 133.
Rock cleavage, Leith, 406; Becker, 407.
Rogers, A. W., Geology of Cape Colony, 163.
Röntgen rays, charging effects, Hahn, 461.
Rutherford, E., radium and uranium in radio-active minerals, 55; slow transformation products of radium, 321.

S

- Shaller, W. T.**, purpurite, a new mineral, 146.
Schneider, H., Soils and Fertilizers, 398.
Schneider, P. T., overthrust faults in central New York, 308.

- Schuchert, C., Catalogue of Fossil Invertebrates, U. S. Museum, 405; mounted skeleton of *Triceratops prorsus* in U. S. Nat. Museum, 458.
 Sedgwick, A., text-book of Zoology, 76.
 Smithsonian Institution, annual report, 412.
 Soils and Fertilizers, Schneider, 398.
 South Africa, glacial conglomerate, Mellor, 107.
 Spectral lines, influence of character of excitation upon structure, 68.
 Spectroscopie, Handbuch, Kayser, 69.
 Stillman, T. B., Engineering Chemistry, 398.
 Switzerland, peat bogs of, Früh and Schrötter, 162.

T

- Talbot, M., revision of the New York Helderbergian Crinoids, 17.
 Taschenberg, O., Bibliotheca Zoologica, II, 412.
 Temperatures, thermo-electric junction for determining, Dewar, 153.
 Trouessart, E. L., Catalogus Mammalium, 470.
 Trowbridge, J., side discharge of electricity, 57.
 Tully quadrangle, geologic map, Clarke and Luther, 158.
 Turkestan, Explorations in, 245.

U

- Uhlig, C., Kilimandjaro to Meru, Africa, 78.
 United States, geol. survey, 69, 402.
 National Museum, Report for 1903, 167.
 — — Catalogue of Fossil Invertebrates, Schuchert, 405.
 Utah, geology of Bingham mining district, Boutwell, Keith and Emmons, 466.

V

- Vapor-densities, apparatus for determining, Harrington, 225.
 Virginia, Cambro-Ordovician limestones, Campbell, 445.
 Voltaic element, normal, 68.
 Voltameter, iodine titration, Kreider, 1.

W

- Walcott, C. D., Cambrian faunas of India, 404, 405.
 Walker, C. F., Inorganic Chemistry, 66.
 Walther, J., Geology, 161.
 Waring, G. A., quartz from San Diego Co., California, 125.
 Water, heat vaporization, mechanical equivalent, Hough, 81.
 Watkins and Elmira quadrangles, geology, Clarke and Luther, 157.
 Washington, H. S., geology of Belknap Mts, N. H., 344.
 Wells, H. L., Text-book of Chemical Arithmetic, 399.
 Wieland, G. R., new Niobrara *Toxochelys*, 325; Upper Cretaceous turtles, 430.
 Wright, F. E., optical character of birefracting minerals, 285.
 Wyoming, new *Ceratopsia*, Hatcher, 413; restoration of *Diceratops*, Lull, 420.

Y

- Yerkes Observatory, report, 411.

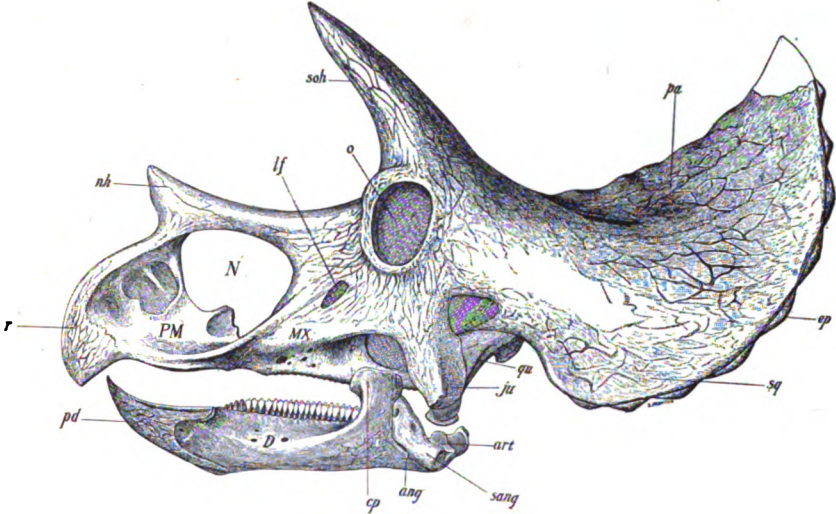
Z

- Zoologica, Bibliotheca, II, Taschenberg, 412.
 Zoology, text-book, Sedgwick, 76.

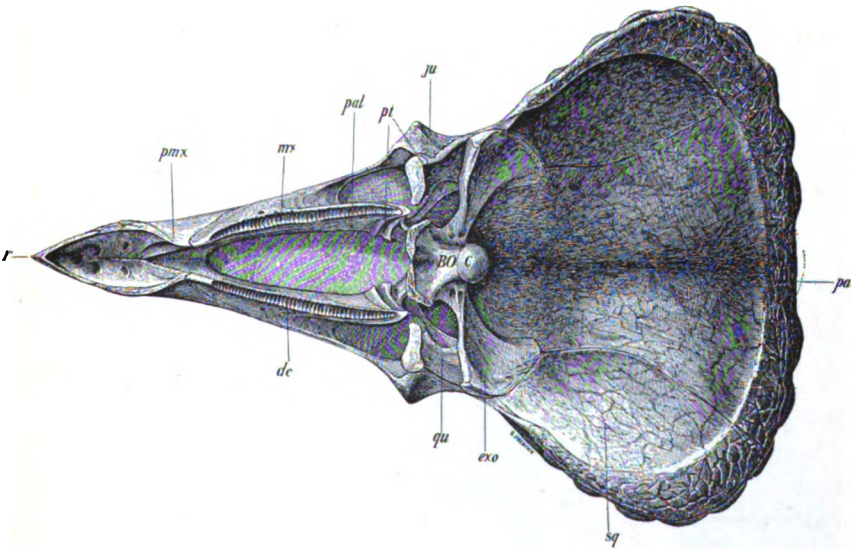
ZOOLOGY—

- Annelids, tubicolous, from the Pacific, Bush, 75.
 Birds' Eggs, catalogue, British Museum, Oates, 412.
 Cold Spring Harbor Monographs, 78.
 Diptera, No. American, catalogue, Aldrich, 77.
 Fauna of Maldives and Laccadives, Gardiner, 77.
 Goat, Rocky Mt., Grant, 77.
 Insects, Habits and Instincts, Fabre, 77.
 Mammalium, Catalogus, Trouessart, 470.
 Protozoa of Connecticut, Conn. 76.
 Tunicata, British, Alder and Hancock, 469.

1

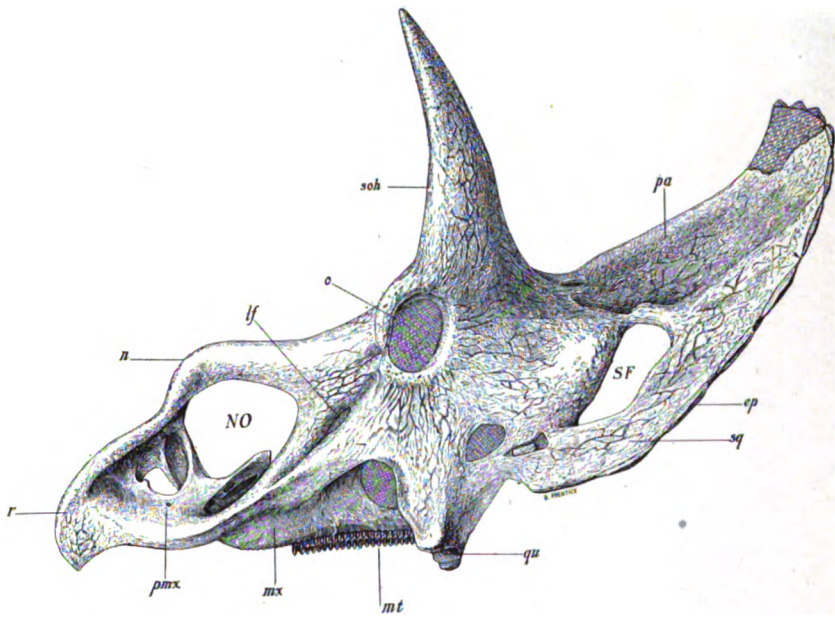


2

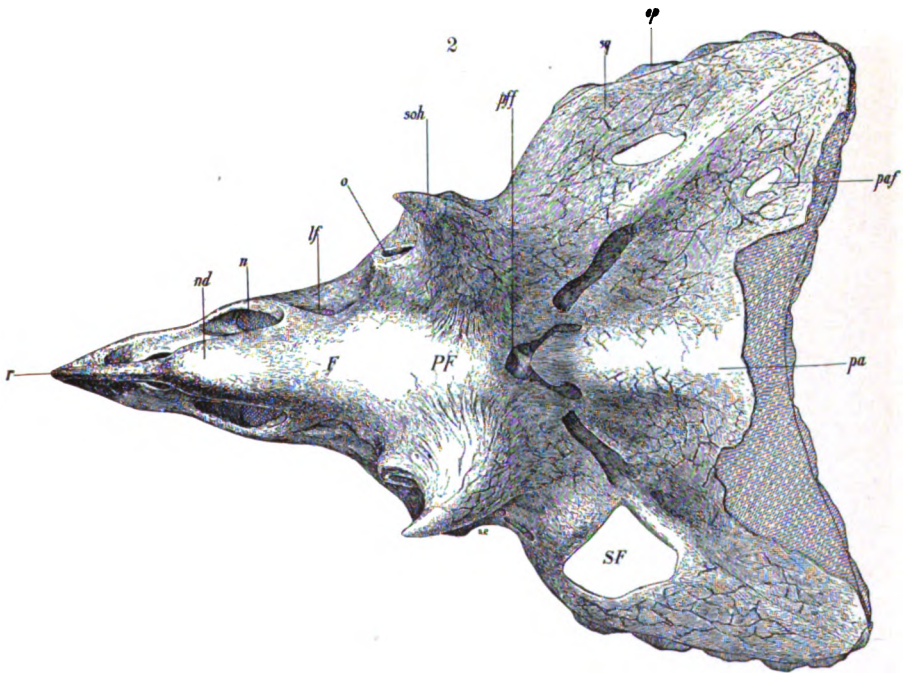


Triceratops brevicornus Hatcher, one-sixteenth natural size.

1



2



Diceratops hatcheri Lull, one-sixteenth natural size.

1



2



Restoration of *Diceratops hatcheri* Lull, from a model by the author.

The upper figure is that of the front view of the model with the muzzle somewhat depressed.

